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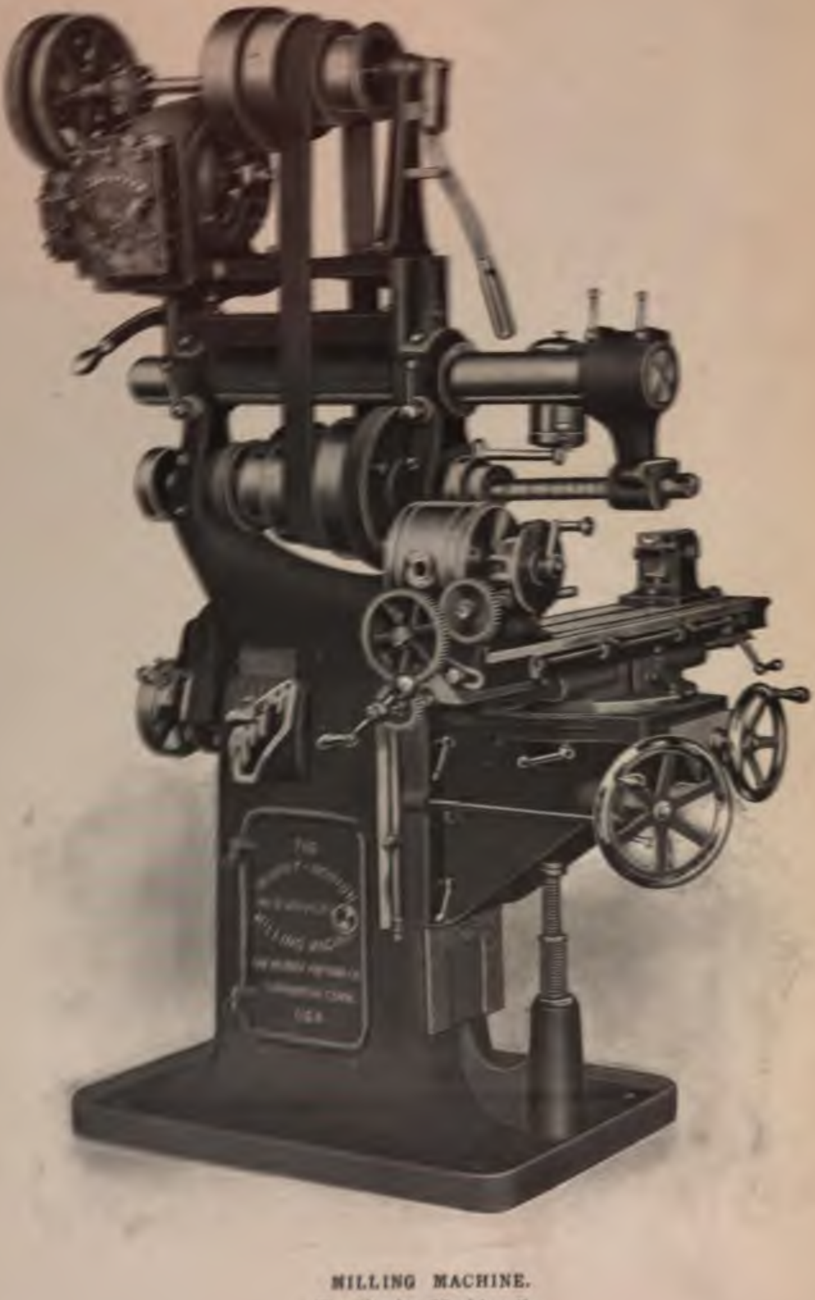

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CYCLOPEDIA

OF

Modern Shop Practice

A Manual of

SHOP PRACTICE, PATTERN MAKING, MACHINE DESIGN, FOUNDRY
AND MACHINE SHOP WORK, FORGING, TOOL MAKING,
SHEET METAL WORK, STEAM, GAS AND OIL
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VOL 1

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HOWARD MONROE RAYMOND, B. S.
DEAN, ARMOUR INSTITUTE OF TECHNOLOGY

Assisted by a Corps of

SHOP EXPERTS, DESIGNERS AND ENGINEERS

Illustrated with over Two Thousand Engravings

FOUR VOLUMES

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost engineering firms, in making these volumes thoroughly representative of the best and latest practice in the design and construction of steam and electrical machines and machine tools; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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Introductory Note

THE successful education of the man in the shop is a question of vital importance. The difficulties under which he toils in his struggle for advancement, and his daily labor, render impossible the usual means of education, and prevent the attending of a resident technical school. Probably the most successful substitute for such a school is the correspondence method of instruction.

¶ Thousands of mechanics are improving their condition by devoting a half hour each day to systematic study under the direction of men who have had long experience in teaching, and in practical shop work. There are, however, many who cannot afford the time and expense necessary for a correspondence school course. For such the Cyclopedia of Modern Shop Practice is prepared.

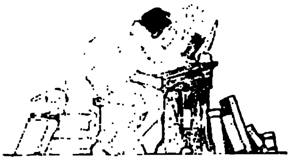
¶ The instruction papers forming the Cyclopedia have been prepared especially for home study by acknowledged authorities, and represent the most careful study of actual shop needs and conditions. Although primarily intended for correspondence study, many are in use as text books by Harvard University, Columbia University, Lehigh University, Iowa State College, the University of Maine, the U. S. Government in its School of Submarine Defense, the Westinghouse Companies in their Shop School, and for reference in the leading colleges, shops and public libraries.

¶ Years of experience in the shop, laboratory, and class-room have been required in the preparation of the various sections of the Cyclopedia. Each section has been tested, by actual use, for its practical value to the man who desires to know the latest and best practice in the shop or engine room.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a text book with a reference work.

¶ Grateful acknowledgment is due to the corps of writers and collaborators, who have prepared the many sections of this work. The hearty co-operation of these men—engineers of wide practical experience and acknowledged ability — has alone made these volumes possible.

¶ The Cyclopedia has been compiled with the idea of making it a work thoroughly technical yet easily comprehended by the man who has but little time in which to acquaint himself with the fundamental branches of practical engineering. If, therefore, it should benefit any of the large number of workers who need, yet lack, technical training, the editors will feel that its mission has been accomplished.



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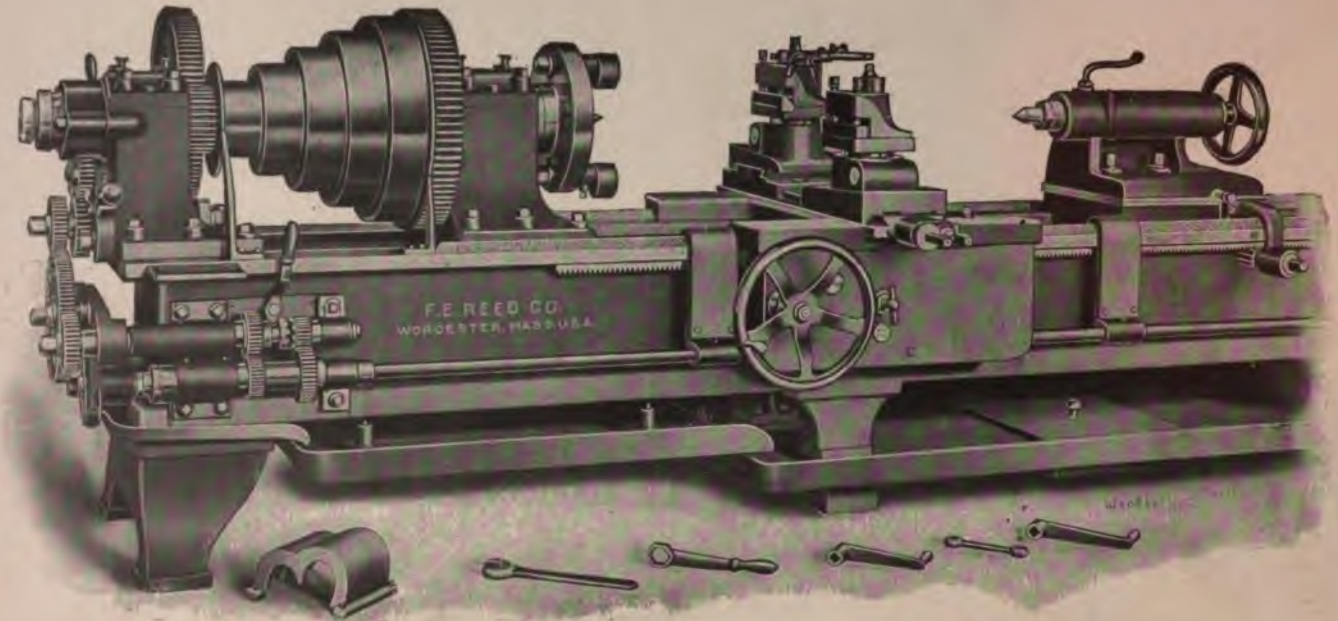
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MACHINE SHOP WORK.

PART I.

Machine shop work is usually understood to include all cold metal work in which a portion of the metal is removed to make the piece of the required shape and size either by power-driven or hand tools. However, there are some branches of cold metal work, such as sheet-iron work and coppersmithing, that are not included in machine shop work.

HAND-OPERATED TOOLS.

As the hand-operated tools are much simpler, and as the operations performed with them are in every case more typical, their description and use should precede that of power-driven tools. It should be clearly understood, however, that machine shop practice involves the use of both classes at the same time. Even hand tools are not used in the same order on different classes of work; it is, therefore, impossible to describe them in the order of use. Simplicity of construction and operation will be the guide for treatment in the following pages.

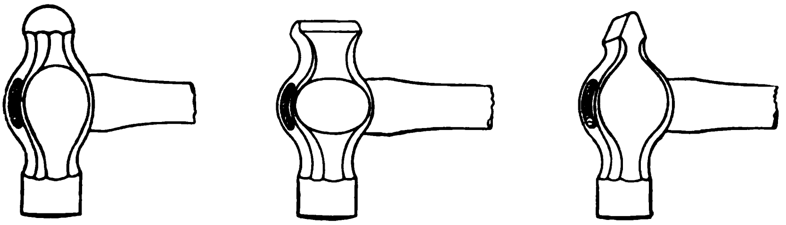

Fig. 1.

The machinist uses **hammers** of three shapes: ball pene, cross pene, and straight pene. See Fig. 1. The first named, the ball pene, is the most common; it varies in weight from four ounces to three pounds. The cross and straight pene hammers vary from four ounces to two pounds and are used principally in riveting. All hammers are made from a good grade of cast steel, hardened, and drawn to a blue color at the eye and a dark straw on the face and pene. The eye is elliptical in shape, and the handle is fastened by driving wedges, either wood or iron, into the end of the handle, thus spreading it to fill the eye. The handle is of hard wood, preferably hickory, and of a length suited to the weight of the hammerhead. When the handle is properly inserted, the axis of the head stands at right angles to the axis of the handle.

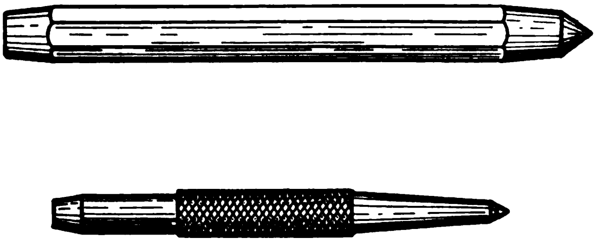

Fig. 2.

Soft hammers are used for striking heavy blows where the steel hammer would bruise the metal or mar the surface. They are made of rawhide, copper, or Babbitt metal, and vary in weight from six ounces to six pounds. They are subject to rapid wear, but are indispensable in setting up and taking down machinery. Those of metal are so constructed that the soft metal can be recast in the handle.

Fig. 3.

The *prick punch*, Fig. 2, is made of cast steel with a hardened conical point of about 60 degrees. It is about 3½ inches long and ¼ inch in diameter. It is used for making very small holes at intervals of about ½ inch on a line.

The **center punch**, also shown in Fig. 2, is made of the same general appearance as the prick punch, but is about 5 inches long, ½ inch in diameter, and has a point of about 90 degrees. The principal use is to make center holes marking the centers on the ends of pieces to be turned.

Both prick punches and center punches are usually made of hexagonal steel; but if round stock is used, the grip should be fluted or knurled to prevent slipping in the fingers.

The **scriber** or **scratch awl**, Fig. 3, is made in many forms, but consists essentially of a cast-steel rod about 8 inches long and $\frac{3}{16}$ inch in diameter, with a long, slender, hardened point at each end; frequently one point is bent at right angles to the shank. As the name indicates, this tool is used for marking lines on the surface of metal.

The **surface gauge** is used in laying out work for the bench, lathe, or planer. The ordinary form consists of a heavy base, an upright, and a scriber or scratch awl; the upright being firmly fastened to the base. In the universal gauge, the upright is pivoted at the base so that it may be used at any angle. In some forms the base is grooved in order that the gauge may be used on cylindrical work as well as on flat surfaces. See Fig. 4.

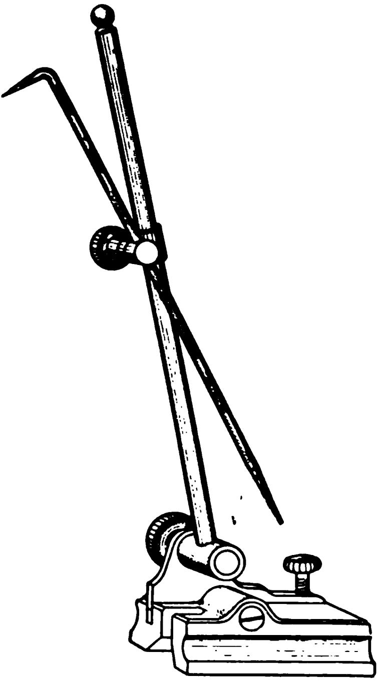
Fig. 4.

To use the gauge, the part of the work to be laid out must be prepared so that lines drawn on the surface will show distinctly. A rough or unfinished surface is covered with chalk, a finished or bright surface should be copper-plated by applying a thin coating of copper sulphate solution with a brush or a piece of waste. The work and gauge are then placed on a true surface and the scriber adjusted to the desired height. The line is drawn by moving the surface gauge along on the true surface, keeping the point in contact with the work. After scribing the lines, it is well to place light prick punch marks at frequent intervals along the lines, so that the position may be found if the chalk or copper sulphate becomes effaced.

The **straight edge** consists in its simplest form of a thin flat piece of steel, generally hardened, with accurately finished straight edges. The very small sizes used in fine work are sometimes made with a beveled knife edge. A non-conducting handle is sometimes used with the small sizes to prevent distortion from the unequal heating due to handling. The short lengths used for ordinary shop purposes have one edge beveled, and are thick enough to avoid bending. See Fig. 5. The larger sizes, from three to ten feet or more in length, are usually made of cast iron with one finished edge. The metal is so distributed as to combine lightness with great rigidity, the tendency of the ends to drop being resisted by the truss-like form of the casting shown in Fig. 6. The flat form is used, in connection with the scriber, to draw accurate straight lines on plane surfaces. All styles are used to test the truth of plane sufaces by placing the straight edge on the surface to be tested in not less than the six positions shown in Fig. 7.

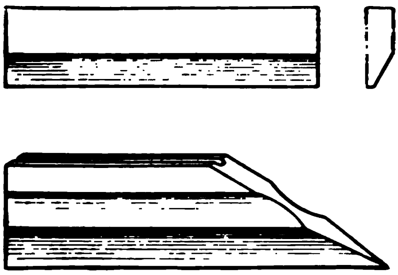

Fig. 5.

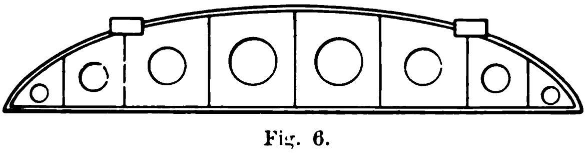

Fig. 6.

For drawing lines and laying off distances on curved surfaces, such as shafts, a combination of two straight edges, or a straight edge and a rule, is used. This is often called a *key seat rule* because its chief use is laying out keys on shafts. However, many machinists call it a "box-rule." It is usually made in one piece, although some manufacturers provide clamps by which the two separate pieces are held at right angles to one another. A more simple combination is shown in Fig. 8, the second scale being represented by two special clamps.

The simplest form of square, called the *flat square* (Fig. 9), is a combination of two straight edges at right angles. This is a useful form where the square is laid on the work. One blade is usually graduated on the inner edge, and the other on the outer edge. The flat square is not hardened.

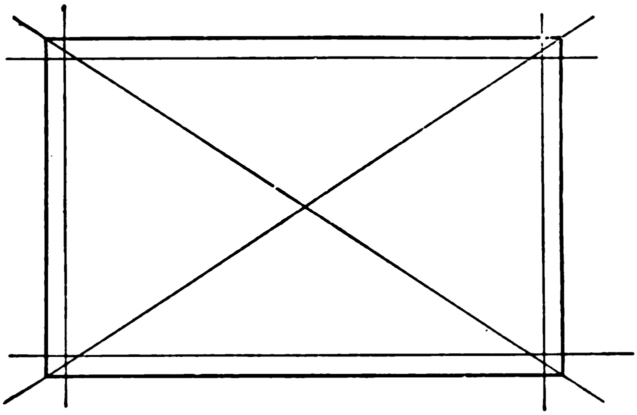

Fig. 7.

The **try square,** shown in Fig. 10, consists of a beam and a blade at right angles. The beam is much thicker than the blade and somewhat shorter. Try squares are made both unhardened and hardened. The unhardened form has graduations on one edge, and is called the graduated try square. The hardened type always has a hardened blade, sometimes a hardened beam as well, and is not graduated.

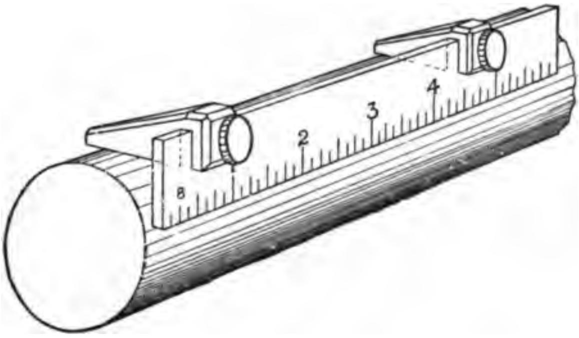

Fig. 8

The try square is used as a guide to draw lines at right angles to each other and to given surfaces; to erect and test perpendiculars to plane surfaces; to test the truth of a given surface at right angles to another surface; in short, it is used wherever an accurate measurement of 90° is required. When used for testing the relation of two surfaces, the beam is pressed closely against the correct surface, and the blade brought carefully down to the surface under consideration. This does not prove more than that a line at the particular point tested is or is not at right angles to the true surface. By using the blade as a straight edge parallel to the true surface, errors in that direction may be corrected and the surface be made plane.

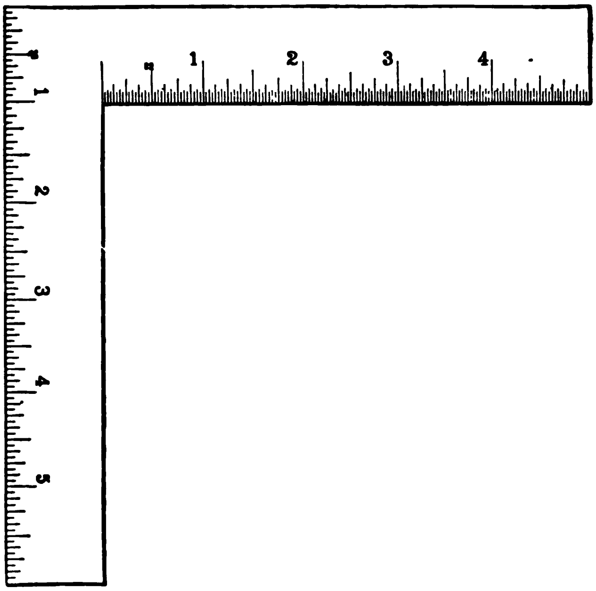

Fig. 9.

In many cases it is necessary to test the relation of lines and surfaces which are not at right angles to each other. For this purpose a **bevel** is used in which what corresponds to the blade of the square is made adjustable. Its construction is seen in Fig. 11, and its use is similar to that of the square.

The bevel can be adjusted only by direct application to lines or surfaces having the proper angular relation. It often happens that such adjustment is not feasible, and therefore a registering device, in the form of a graduated arc, is applied to the bevel, making what is known as a **protractor,** shown in Fig. 13. This tool can be used to find the angular relation in degrees or to produce that relation by setting to the proper point on the graduated arc.

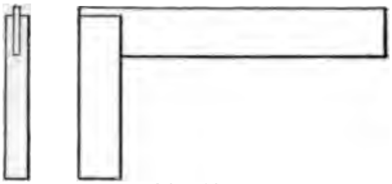

Fig. 10.

As the center of a circle is found at the intersection of any two diameters, an instrument for readily finding that point is a great convenience. In Fig. 12 is shown a combination of straight edge and square called a **center square,** which accomplishes this result. As one edge of the rule bisects the angle of the square, it is evident that a line drawn by that edge passes through the center of any circular piece to which the square is applied. Centering the ends of round bars or circular work of any kind is the principal use of this tool.

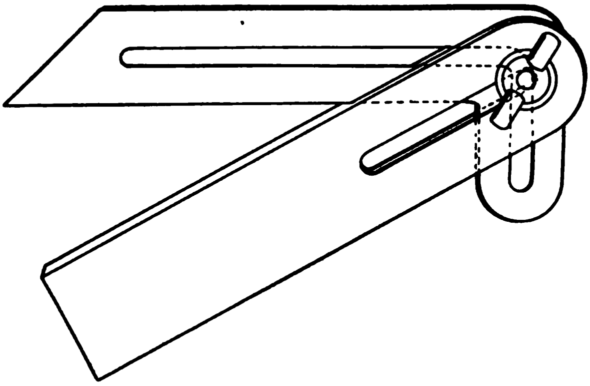

Fig. 11.

The center square, bevel, and protractor are furnished in a combination set as shown in Fig. 14. The ability to change the length of the blade is one of the great benefits of this construction.

MEASURING TOOLS

The testing tools thus far described are used for comparing the angular relation of lines and surfaces, and may be called tools for angular measurement. We now turn to the consideration of instruments for measuring distances and sizes, or tools for linear measurement.

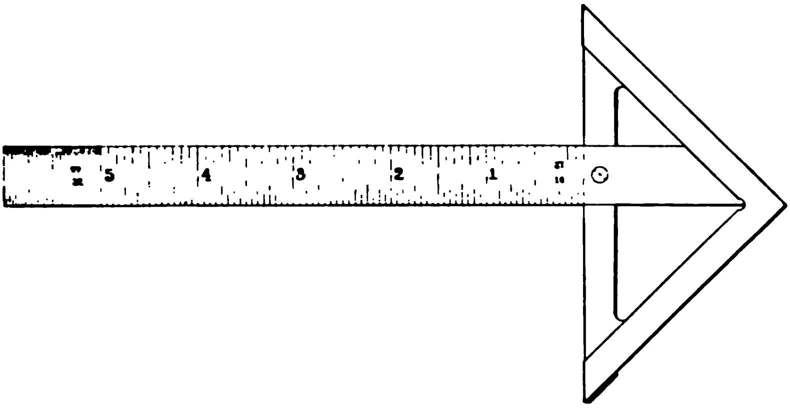

Fig. 12.

The most common tool for *linear measurements*, and one which hardly requires description, is the so called carpenter's or two-

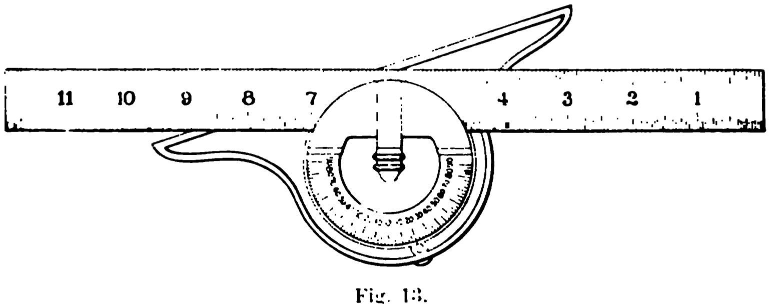

Fig. 13.

foot rule. This is very convenient for the machinist in making measurements which are not required to be very accurate. For work of greater refinement, the **standard steel scale** (Fig. 15) is used. This is in reality a divided or graduated straight edge and, as such, forms a part of several tools already described. The most common form of steel scale is flat, varying from one to forty-eight inches in length, and carefully hardened and ground. The graduations in the better class of scales are cut with a dividing engine, although the lines may be etched on the surface with a fair degree of accuracy. A thin and somewhat narrower form, called a flexible scale, is made in sizes from four to thirty-six inches. What are known as narrow scales are obtainable from four to thirty-six inches, and are of great convenience in certain cases. Besides these shapes, square scales are made in sizes from three to six inches in length, and the triangular form varies in length from three to twelve inches. Steel scales with the English system of graduation can be obtained with the inches divided in eighths, sixteenths, thirty-seconds, sixty-fourths; twelfths,

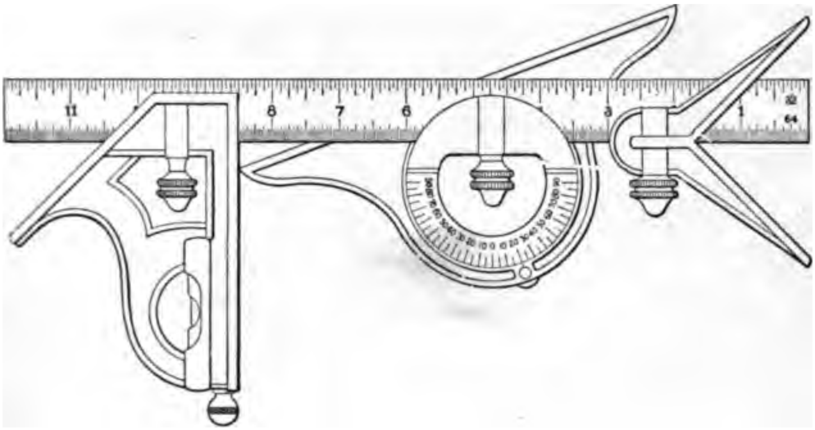

Fig. 14.

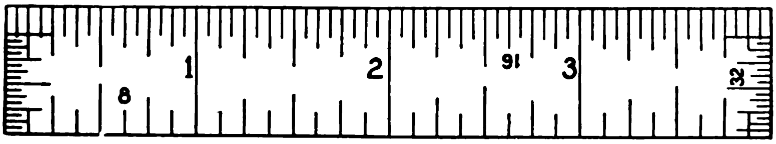

Fig. 15.

MEASURING TOOLS

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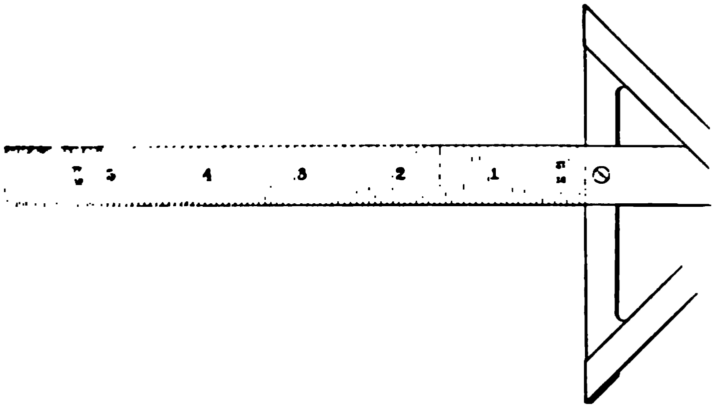

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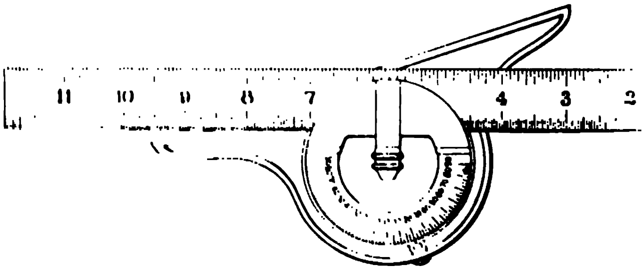

Fig. 13.

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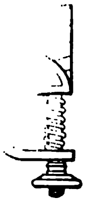

blunt points. As dis-
inside of solid bodies,
legs of outside calipers
ers may be passed over

ke dividers in general ap-
d slightly and the points
d in dividers are used in
designated by the distance
Spring calipers are made

twenty-fourths; tenths, twentieths, fiftieths, and hundredths. Special scales are made with graduations especially adapted to such uses as gear blank sizing, etc.

The ends of flat rules are sometimes graduated, making what might be called a very short rule with a handle. Flat rules are sometimes graduated with Metric divisions as fine as one millimeter, and from five centimeters to one meter in length.

For transferring and comparing distances, **dividers** are commonly used. They are classified according to the style of joint and the length of the leg. The most simple joint is the friction, and like all frictional devices, is hard to set accurately. Lock-joint dividers can be moved freely to approximately the right position, the joint locked, and the adjusting screw used for the final setting.

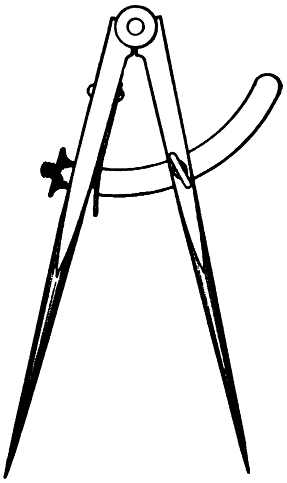

Fig. 16.

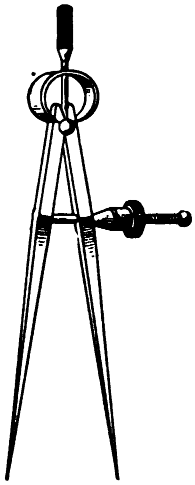

Fig. 17.

Wing dividers, Fig. 16, are of about the same construction as the lock joint, except that the fastening is made on the wing instead of at the pivot. The best of all forms has a spring adjustment as shown in Fig. 17. In this type, a spring tends to open the dividers, and the legs are closed against the spring by a nut working on a screw which is fastened to one leg and passes freely through the other. The length of dividers varies from two and one-half to ten inches. The distance to which dividers can be opened is generally about equal to the length of the leg. For distances above ten inches, ***trammel points***, diagram, Fig. 18, are convenient. They consist of hardened steel points attached to metal sockets, and can be used on rods of any length. One point may have a spring adjustment, and in that case can be set in the same manner as a pair of wing dividers.

Next in importance to the dividers as an adjustable distance gauge, are the **calipers.** Instead of having straight legs with sharp points, caliper legs are bent and have blunt points. As distances are to be measured both outside and inside of solid bodies, we have outside and inside calipers. The legs of outside calipers have a large curvature so that the calipers may be passed over cylinders of their greatest capacity.

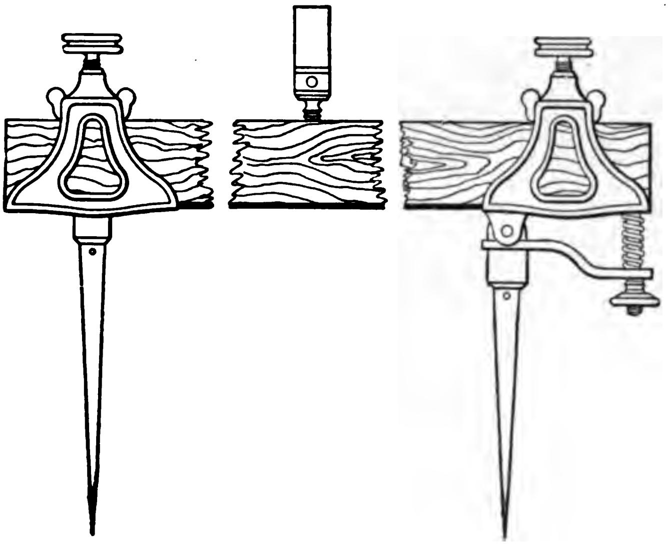

Fig. 18.

Inside calipers, Fig. 20, are more like dividers in general appearance, the ends being bent outward slightly and the points rounded. The same styles of joints used in dividers are used in calipers, and the size of calipers is also designated by the distance from the joint to the end of the leg. Spring calipers are made in sizes from two and one-half to eight inches, while the other styles vary up to twenty-four inches.

As it is sometimes necessary to make measurements behind shoulders and in chambered cavities, where the ordinary calipers could not be removed after setting, it is necessary to have calipers so arranged that they may be set, changed to clear the obstruction, and then reset accurately in the first position. This is accomplished by **transfer calipers,** shown in Fig. 19, in which one leg is temporarily fastened to a stub or false leg. After setting, this leg may be moved away from the stub, the calipers withdrawn, and the leg again placed in contact with the stub; the points will then be found to occupy the same position as when first set. Small curved legs may be used in place of points or trammels in calipering large objects.

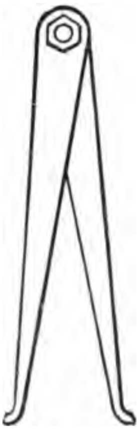
Fig. 20.

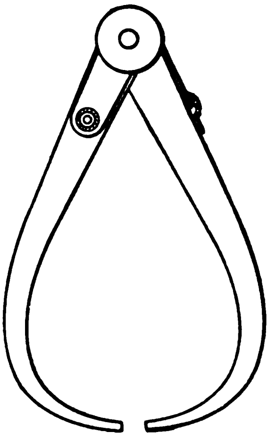
Fig. 19.

Both dividers and calipers are usually set by means of a scale. In setting dividers, place one point in a graduation of the scale, and move the other until it falls easily into another graduation which gives the required distance. Outside calipers are often set by placing one leg against the end of the scale and moving the other until it is opposite the middle of the graduation giving the required length. As the graduations are not mathematical lines, but have an appreciable width, this last precaution is one of great importance. Inside calipers are set by placing both the scale and caliper toe against a plane surface as shown in Fig. 21; the other toe is then set the same as the outside caliper.

Caliper legs are comparatively slender, are easily bent, and care must be taken in using them to see that the contact with the object being tested is very light. It is an easy matter to spring calipers of common sizes as much as one-sixteenth of an inch.

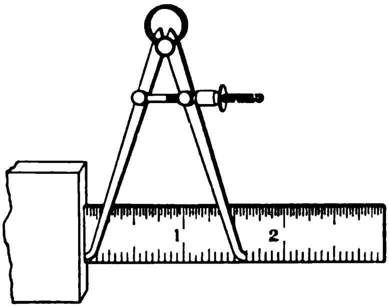

Fig. 21.

The **caliper square** is made by attaching a movable blade to the common square. In the ordinary forms it closely resembles a steel rule with two arms extending from it at right angles, one fixed near the end and the adjustable arm sliding along the scale with a clamping device for adjusting this movable arm. In order that the movable arm may be set accurately, caliper squares (Fig. 22), as at present constructed, have two clamps for the movable arm. The one carrying the thumb nut is to be first clamped in approximately the right position; the clamp on the movable arm being secured after the adjustment has been made by the nut. The sizes used vary from three inches up, and are limited only by the length of scales obtainable.

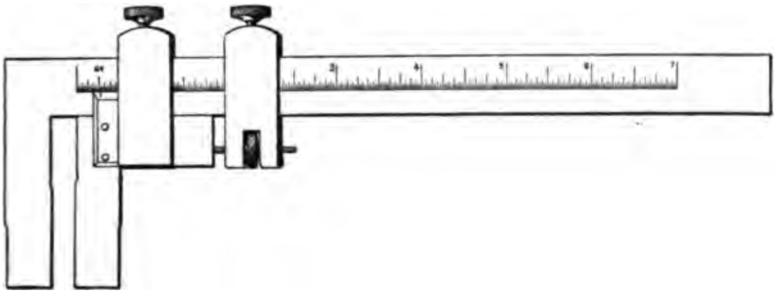

Fig. 22.

For measurements which are required to be more accurate than can be obtained by the preceding forms of calipering devices, the

micrometer caliper, Fig. 23, is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

It consists, essentially, of a crescent-shaped frame carrying a hardened steel anvil B at one end and a nut of fine pitch at the other; the axis of the nut being at right angles to the face of the anvil. The outside of the nut, A, forms a projection beyond the crescent that is called the barrel. The measuring screw consists of a fine-pitched screw to fit the nut, combined with a measuring point C, having a face parallel with that of the anvil. Firmly attached to the outer end of this screw, is a thimble D, fitting closely over the barrel; the edge of this thimble is beveled so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel indicates a movement of the measuring point of one thousandth of an inch. For example: if the pitch of the measuring screw is one hundredth of an inch, there should be ten divisions on the

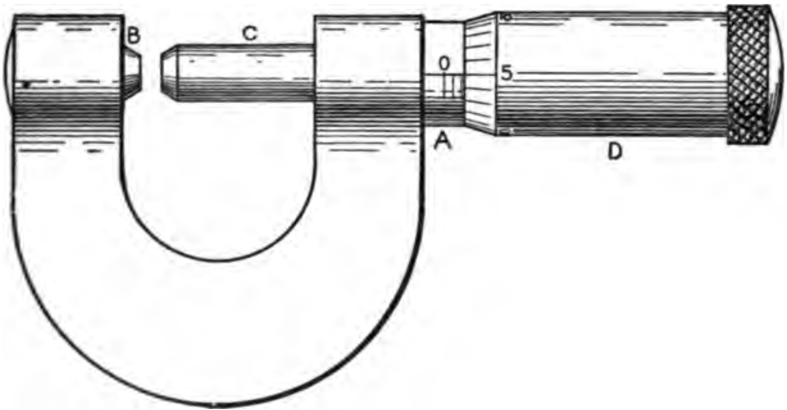

Fig. 23.

thimble; if one fiftieth of an inch, twenty divisions; if one fortieth of an inch, twenty-five divisions; if one twenty-fifth of an inch, forty divisions. Measuring screws having a pitch of one fortieth of an inch are commonly used, and every fourth division on the barrel lengthened and numbered to indicate tenths of an inch as shown in Fig. 25.

In using the micrometer caliper, it should not be set at the size required and pushed over the work, but should be screwed down until the measuring point C and anvil B are in contact with the work; the size may then be read from the relation of the thimble to the reference line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble so that undue pressure cannot be exerted.

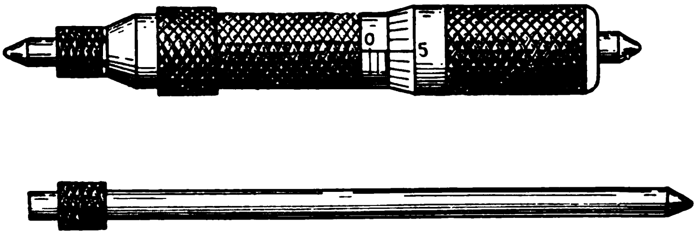

Fig. 24.

The micrometer caliper will not only indicate that the work is too large or too small, but will also show exactly the amount by which it differs from the desired measurement. This is a great improvement over the rigid form of calipers, and enables the workman to judge more accurately the progress of the work. This form of caliper is rapidly coming into favor in spite of its cost, and for this reason it has been described more at length than the common forms previously considered.

The range of motion of the measuring screw is usually limited to one inch. Various devices give the micrometer caliper a larger range of action. Micrometer calipers may now be purchased in combinations or sets giving a range from zero to twelve inches.

The application of the micrometer principle to inside measurements is not in general use, but is easy to arrange, and makes a very simple instrument, as shown in Fig. 24. It consists of an ordinary micrometer head, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. Two inches is about the shortest distance that can be measured with this device, but there is hardly any limit in length, as the rigidity of the rod is easily provided for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, and thus limits this form to about 12 inches, as above stated. The contact points in the outside type are parallel plane surfaces, and in the inside form are rounded points of small radius. Outside micrometers are provided with contact points of varying forms for measuring paper, threads, walls of tubes, etc. The shapes for these purposes will not be shown, but may easily be imagined.

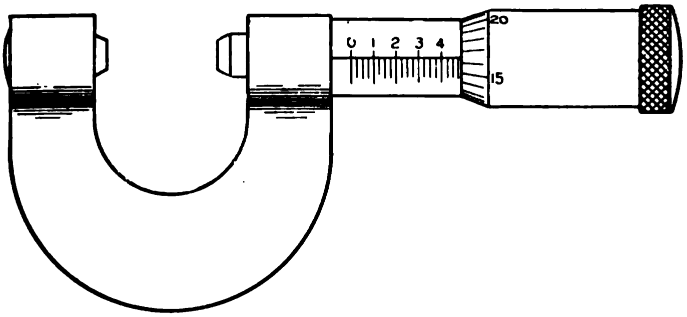

Fig. 25.

Reading the Micrometer. As stated above, the micrometer screw has 40 threads per inch and the thimble has 25 divisions on its circumference. The barrel is divided to correspond to the pitch of the screw with each fourth division numbered. In reading the indicated measurement, first note the highest number visible on the barrel, and call it hundreds of thousands or tenths. (In Fig. 25 it is 400 thousandths or .400.) Then read the short divisions on the barrel, calling the first division 25 thousandths (.025), the second 50 thousandths (.050), and the third 75 thousandths (.075). In this figure the third division is the last one visible. Now read the number indicated on the thimble; that is

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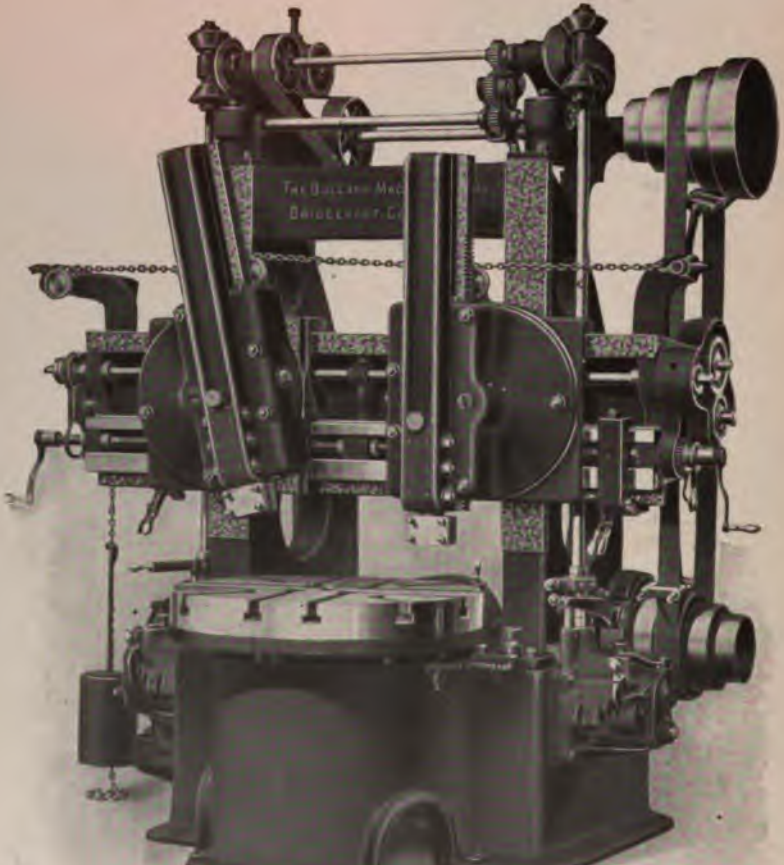


42-INCH RAPID PRODUCTION MILL.
The Bullard Machine Tool Co.

the number that has passed the line running lengthwise. In the figure it is 16; or $16\frac{1}{2}$ if the reading is to be finer than thousandths. Add this reading to the readings of the short divisions, thus: $75+16\frac{1}{2}=91\frac{1}{2}$; this is $.091\frac{1}{2}$. Adding the .400 to this we get $.491\frac{1}{2}$. This means that the distance from the anvil to the measuring-point is $\frac{4915}{10000}$ of an inch, or .4915 inch. If the micrometer caliper is a good one, we may be sure the distance is between .491 inch and .492 inch.

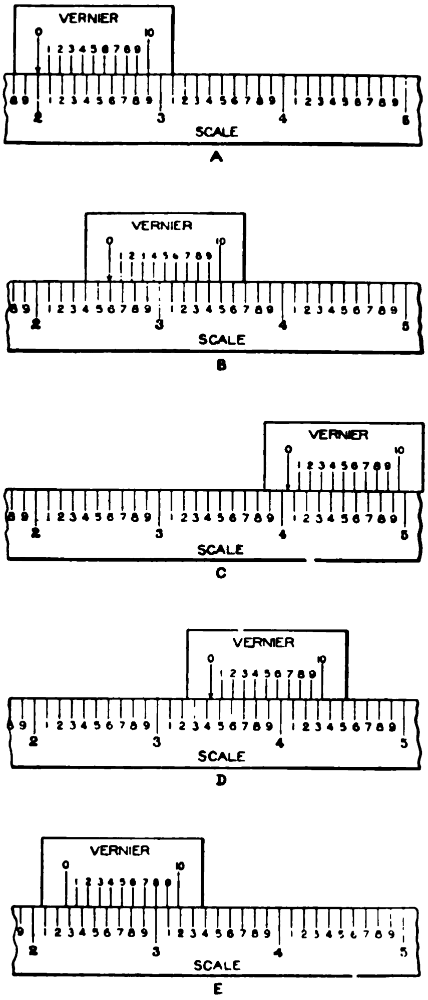


Fig. 26.

The Vernier. As has already been stated, the finest graduation that can be easily read on a steel rule by the naked eye, even after much practice, is one-hundredth of an inch. With the growing refinement in measurements, it was found necessary to obtain readings finer than this, and a method of subdivision, known from the name of the inventor, as the "Vernier," was adopted. The principle will first be explained. (See Fig. 26.)

Let two rules be so graduated that the true scale has each inch divided into ten equal parts, and the Vernier scale has ten divisions occupying the same space as nine of the divisions of the scale. It is evident that one of the divisions on the Vernier is equal to $\frac{9}{10}$ of one of those on the scale. Now, if the Vernier be moved to the right so that the graduations marked

1 shall coincide, the Vernier will have moved one tenth of a division on the scale, or one hundredth of an inch; when graduations numbered 5 coincide, the Vernier will have moved five hundredths of an inch; when lines marked 0 and 10 coincide, the Vernier will have moved nine hundredths of an inch; and when 10 on the Vernier comes opposite 10 on the scale, the Vernier will have moved ten hundredths of an inch, or the whole of one division on the scale. By this means the scale, although graduated only to tenths of an inch, may be accurately set at points whose positions are expressed in hundredths of an inch.

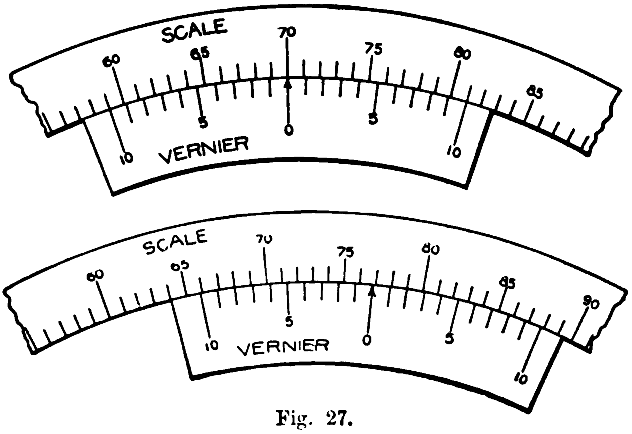


Fig. 27.

Let us consider Fig. 26. At A the Vernier is shown with the 0 in line with 2 on the scale; hence the reading is 2.000.

In B, the 0 of the Vernier has moved to the right beyond the division marked 5. The line 9 on the Vernier is in line with a line on the scale; hence the reading is 2.59.

In C, the zero of the Vernier has moved to the right still farther. The reading is evidently 4.05.

In D, the reading is 3.43.

In E, the reading is 2.28.

While arcs of small radius can be easily graduated into degrees, it is not possible to subdivide the degree without making the divisions confusing. By aid of the Vernier placed just above the true scale representing degrees, readings can be made with accuracy to one-tenth of a degree, or six minutes. The divisions of such a Vernier scale are shown in Fig. 27, and are also shown when set to read 76° 48′.

The most common application of the Vernier to linear measurements is found in the Vernier caliper square. The one shown in Fig. 28 reads to one-thousandth of an inch. Each inch of the true scale, or beam of the instrument, is divided into 40 parts (every fourth graduation being emphasized), while the Vernier, or sliding-scale, has 25 divisions, occupying the same space as 24 divisions on the true scale. By the reasoning used in connection with Fig. 26 the difference in length of one division on the Vernier, as compared with one of those on the true scale, is equal to one twenty-fifth of one fortieth or one thousandth of an inch. The caliper square shown in Fig. 28 is set at .279 inch. The scale is also shown enlarged in which the reading is 1.31 inch.

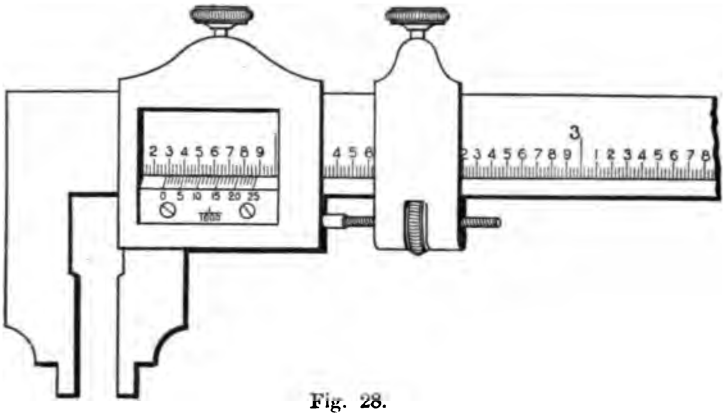


Fig. 28.

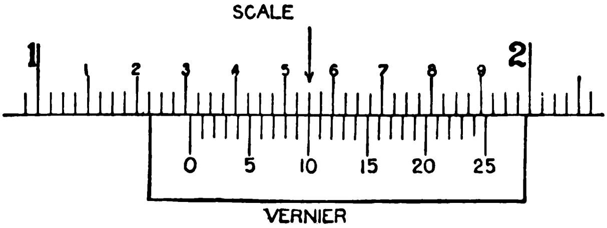


Fig. 28a.

By the use of the Vernier in connection with the micrometer caliper, readings are easily made to one ten-thousandth of an inch.

As shown in Fig. 29, lines are drawn on the barrel parallel to the reference line, making ten equal divisions occupying the same space as nine divisions on the thimble. Referring to Fig. 30, it will be seen that each division on the thimble may be accurately divided into ten parts, each indicating a difference in the position of the measuring point of one ten-thousandth of an inch. Rapid reading of the Vernier in any form can only be acquired by practice, but the following directions may be found helpful:

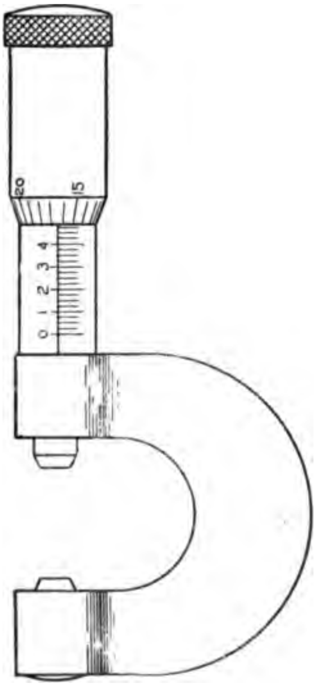


Fig. 25.

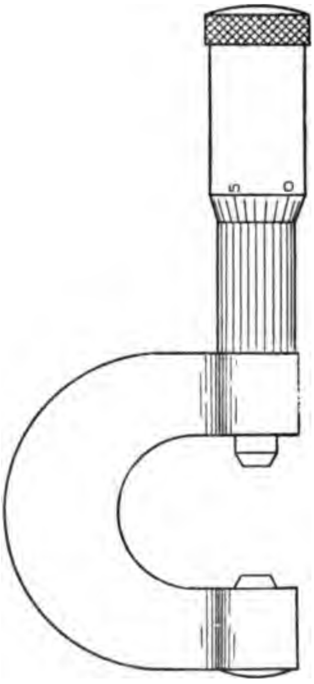


Fig. 29.

In Reading the Vernier, we must bear in mind the fact that each division on the Vernier is $\frac{9}{10}$ of one division on the scale, and that if line No. 1 on the Vernier is in line with any division of the scale the zero of the Vernier is $\frac{1}{10}$ of one division away from the graduation below it; if line No. 2 is in line, the zero is $\frac{2}{10}$ away from the graduation; if line No. 6 is in line, the zero is $\frac{6}{10}$ away.

Suppose the Vernier is in position on the scale and graduated as shown in Fig. 30. First read the highest division on the scale to the left of the zero on the Vernier. (69 is the division in the figure.) Then follow along the scale (to the right) until two graduations are found that are in line, as at 6 on the Vernier and 75 on the scale. Now, since one division on the Vernier means that the zero is $\frac{1}{10}$ of a division of the scale away, six divisions of the Vernier means that the zero is $\frac{6}{10}$ away; hence the zero of the Vernier is $\frac{6}{10}$ beyond the 69, and the reading is 69 and $\frac{6}{10}$ or 69.6.

Arcs of circles, such as are on surveyor's instruments, may be graduated to read to half degrees if the diameter is about 8 inches. Now, if we put on the circle a Vernier graduated so that we have 30 divisions equal to 29 divisions of the scale (arc), we can read 30ths of half degrees or *minutes*.

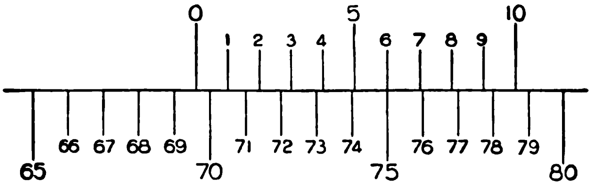


Fig. 30.

Vernier Micrometer. To get very accurate readings, a Vernier scale is placed on the barrel of the micrometer caliper. Let Fig. 29 represent the back side of the micrometer caliper shown in Fig. 25. The reading already obtained was .491 inch. Now turn the caliper over (Fig. 29), and, commencing at the right, count the graduations until one is reached that coincides or is in line with a graduation on the thimble. In doing this, call the first division zero, the second 1, the third 2, etc. The number of the division on the Vernier that is in line with the division on the thimble indicates the ten-thousandths above the regular micrometer reading. From Fig. 29 we see that the 5th line is the graduation which is in line with the division on the thimble which should be called 4, as explained above. Then the reading is .4914 instead of .4915, as we read it from the other side (the plain micrometer). With a good micrometer, we can be sure that the distance between the anvil and the point is more than .4913 and less than .4915.

The Retrograde Vernier. In addition to the direct Vernier, there is another form called the retrograde Vernier, which has 10 divisions on the Vernier and 11 on the scale. In this case the graduations on the Vernier must be reversed, as shown in Fig. 31.

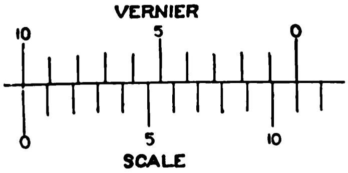
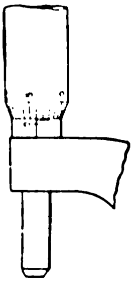


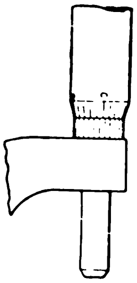
Fig. 31.

Calipers reading to ten-thousandths should not be commonly used when fine measurements are not required, because in an instrument of this class wear is perceptible and important which would be of comparatively little consequence in a caliper that reads only to thousandths.

In using the micrometer caliper for fine measurements, care should be taken in the handling of the instrument. Constant contact with the warmth of the hand will expand it sufficiently to make an error in the reading. The body should be held between the thumb and forefinger of one hand and the thimble turned with the other. It should be laid aside as soon as a reading has been made. It should never be laid upon a piece of cold iron, because the contraction due to chilling is likely to cause an error in the opposite direction from that which would be caused by the heat of the hand.



A



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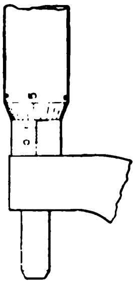

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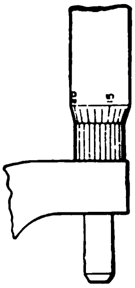


D

EXAMPLES FOR PRACTICE.

1. A micrometer caliper shows a reading of .463 ; how many times must the thimble be turned to produce a reading of .587? Assume 40 threads per inch. Ans. 4$\frac{24}{25}$ times.

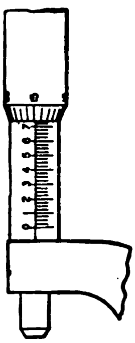
2. What are the readings of the Vernier micrometer calipers shown in Figs. A and B? Ans. .039.

3. State the readings of the micrometer calipers shown in Figs. C and D. Ans. .1546.

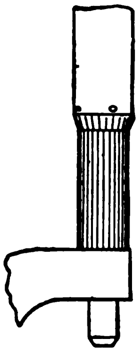
4. Give the readings of the Vernier micrometer calipers shown in Figs. E and F. Ans. .7398.

5. Sketch the front and back of a Vernier micrometer caliper when the reading is .6327.

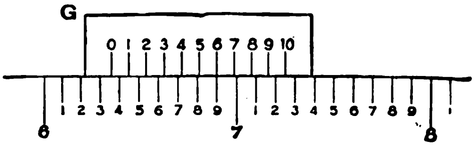
6. What is the reading of the Vernier and scale when in position G? Ans. 6.36.



E



F



Fixed Gauges. While the adjustable gauges that have just been described are available for a large range of work, gauges of one dimension, or fixed gauges, are used to a considerable extent, especially in shops where work of a duplicate character is produced in large quantities. These may be used as standards to which adjustable gauges may be set, or used directly in connection with the work in the same manner as an adjustable gauge. The form of such gauges for comparisons of length is a steel rod with the ends carefully ground so that the distance required may be quickly and accurately determined. In one form the ends are parallel plane surfaces, and in another the ends are sections of a sphere of the same diameter as the length of the rod. Both these forms are illustrated in Fig. 32. Another form of gauge for the same purpose consists of hardened and ground steel disks, Fig. 33, to which calipers and similar tools may be set, and which may be used also to test the size of holes by direct application. For the latter purpose handles are provided by which the disks can be conveniently manipulated.

Plug and ring gauges, as shown in Fig. 34, furnish accurate and convenient standards for the production of duplicate parts of machines. The same result is attained by the caliper gauge shown in Fig. 35, which combines the two gauges in one piece. In this form the external gauge has parallel plane surfaces and the internal gauge is a section of a cylinder. In sizes above three inches, the caliper gauge is usually made in two parts, also shown in Fig. 35, making the tool easier to handle.

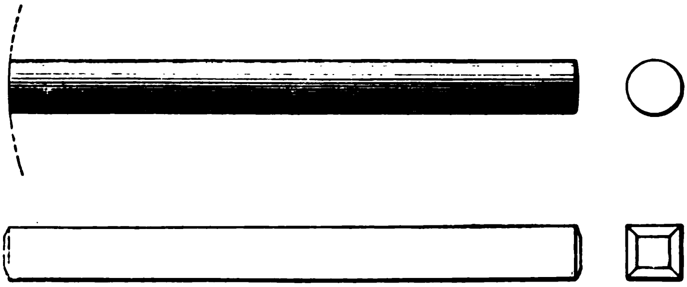


Fig. 32.

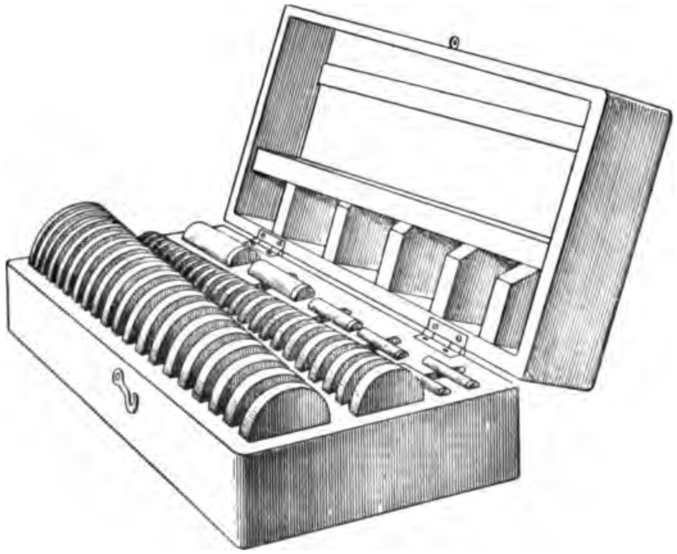


Fig. 33

As is indicated by the cost of these gauges, the exact duplication of such exact sizes in quantities would mean a cost that would be prohibitive in machine construction. The limit of error in the standard gauges just described is never over one ten-thousandth of an inch at a standard temperature, which is usually taken as 70° F. Ordinary machine parts do not require such accuracy,

Fig. 34.

and it is usual to allow a limit of error which is in accordance with the class of work being produced.

For testing sizes and dimensions, both at the machine and in the inspection department, combination gauges, known as **limit gauges,** are employed. These are made both for external and

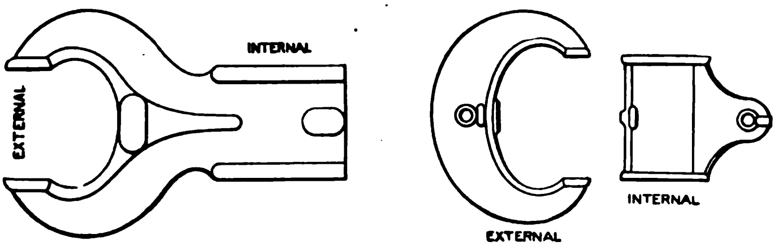


Fig. 35.

internal measurements. The external gauge shown in Fig. 36 is for testing pieces supposed to be .25 inch in diameter. As indicated by the figures on the gauge, the piece is allowed a variation of .0005 inch over, and .001 inch under the nominal size. The words "go on," and "not go on," stamped near the ends, indicate clearly how the gauge is used. This gauge is more conveniently arranged as shown in Fig. 37, in which the work must enter the first parallel opening, but must not pass through the second. In this form, one motion tests the piece for variation above and below the standard. Fig. 38 shows a limit gauge for holes, the end marked "go in" being required to pass into the hole, while the other end marked "not go in," must not enter. An arrangement of the internal limit gauge similar to the external gauge of Fig. 37 is shown in Fig. 39, and has the same advantages.

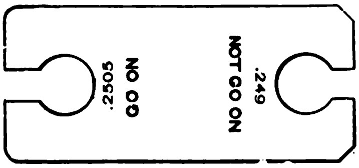


Fig. 36.

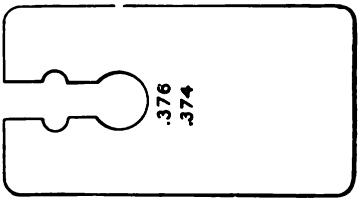


Fig. 37.

In some classes of work, no variation is allowed over the standard, and in others, no variation is allowed under the nominal size. The amount of variation allowed in any case is governed by the class of work and the intended use of the piece. As these allowances are not uniform, such gauges are made only to order.

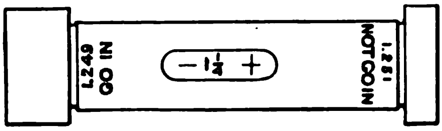


Fig. 38.

For many years gauges of an entirely different character have been used in the measurement of wire, small rods, and sheet metal. The sizes have been designated, not by the diameter or any definite unit, but by a number or letter in a purely arbitrary manner. Even in the same gauge, the sizes do not advance in any regular order. The matter is still further complicated by the fact that in one gauge large numbers indicate large sizes, while in another, the smaller numbers mark the large diameters. Another source of annoyance lies in the fact that such gauges are cheaply made and cannot be relied upon to be duplicates of one another. These gauges were the natural result of the recognition by large manufacturers of the necessity of standards by which to grade their products. Hence we have such gauges as the Brown and Sharpe, Birmingham or Stubs, Washburn and Moen, United States standard, Morse Twist Drill Co., and many others. As a step in the right direction, a decimal gauge has recently been adopted, in which the sizes are indicated by numbers which represent the diameters in thousandths of an inch. Most of these gauges had their origin in days when refined measurements were not common, but since the use of the micrometer caliper has become almost universal, there seems to be no good reason why all sizes should not be expressed in thousandths of an inch, thus avoiding all the troubles incident to the use of the arbitrary gauges.

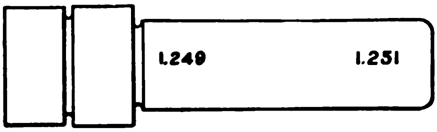


Fig. 39.

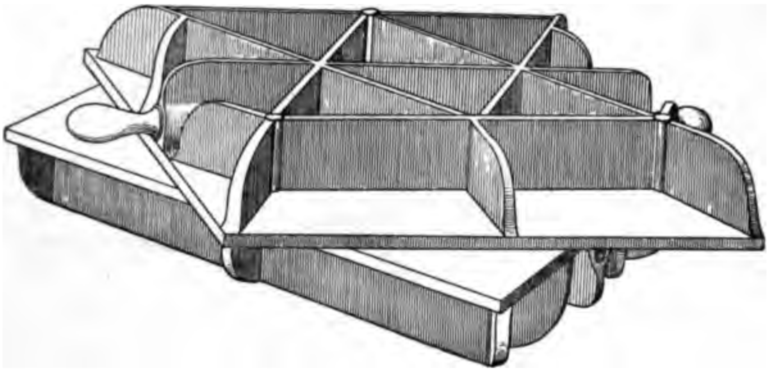


Fig. 40.

For the production of accurate plane surfaces the use of the straight edge is not sufficient. Such surfaces should be compared with standard surfaces called surface plates, Fig. 40. A surface plate is a cast-iron plate strongly ribbed on the back to prevent distortion, and supported on three points to insure a uniform base. The production and use will be described under the head of "Scraping." They may be had in sizes varying from 3 inches by 4 inches to 36 inches by 72 inches.

The machinist's **bench** at which hand work is ordinarily performed should be of substantial character, about two feet ten inches from the floor and two feet six inches wide (see Fig. 41). For the sake of economy it is usual to have a two and one-half or three inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from one-inch stuff. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

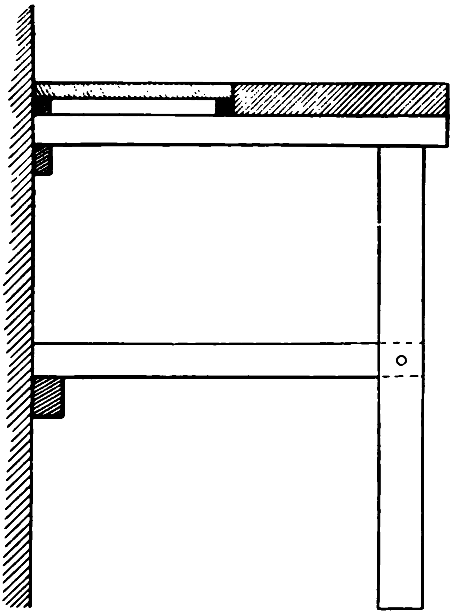


Fig. 41.

In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a ***vise.*** They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 42, shows these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out in the nut.

In the machinist's vise, both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid the marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 42, although a swivel base such as is shown in Fig. 43 is preferable. The vise shown in Fig. 43 has a swivel jaw also which enables it to hold tapered work securely. This swivel jaw is provided with a locking-pin which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaws about one and one-half inches below the point of the elbow when standing erect beside the vise.

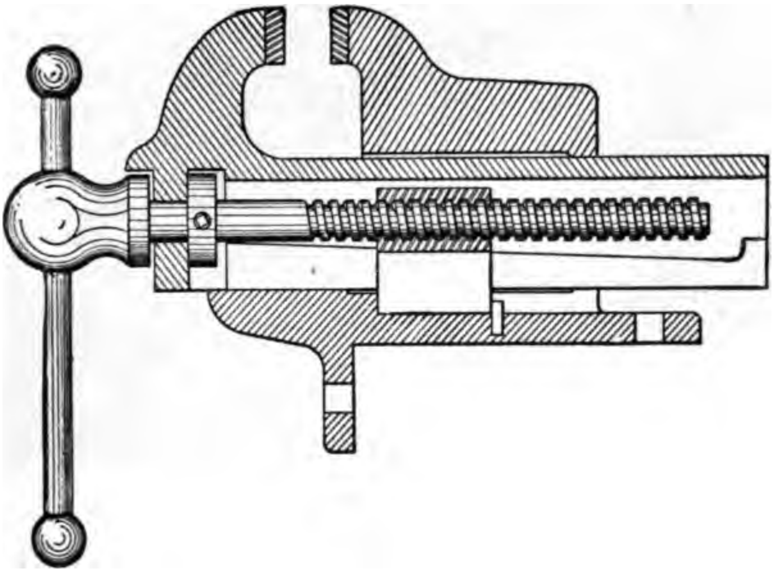


Fig. 42.

CUTTING TOOLS.

The simplest form of metal-cutting tool is the chisel. The several types in common use are shown in Fig. 44. The **flat chisel** is used for snagging castings, for chipping surfaces having less width than the edge of the chisel, and for all general chipping operations. It is the form most commonly used, and is often called the cold chisel. Generally it has a cutting edge about an eighth of an inch wider than the stock from which it is forged. The **cape chisel** is used for cutting key ways, channels, etc., and also for breaking up surfaces too wide to chip with the flat chisel alone. Channels are driven across such a surface, leaving raised portions or "lands" to be removed by the flat chisel. The cutting edge of this chisel is usually one-eighth of an inch narrower than the shank, and the part just in the rear of the cutting edge is made thin enough to avoid binding in the slot. As this weakens the chisel, it is made comparatively thick in the plane at right angles to the cutting edge.

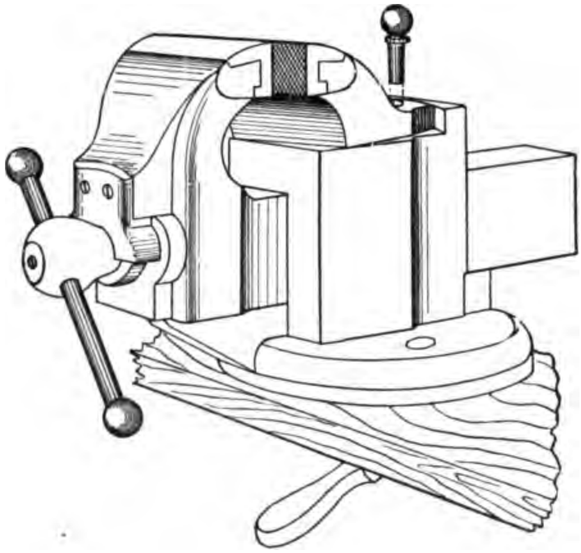


Fig. 43.

The **diamond point** chisel is made by drawing out the end of the stock to about $\frac{5}{16}$ inch square, and grinding the end at an angle with the axis of the chisel, leaving a diamond-shaped point. It is used for drawing holes, making oil grooves, and cutting holes in flat plates.

The **small round-nosed** chisel is cylindrical in section near the cutting end, the edge being ground at an angle of 60° with the axis of the chisel. When used to "draw" the starting of drilled holes to bring them concentric with the drilling circles they are called **center chisels.** This form is also used fo cutting channels, such as oil grooves and similar work. The larger sizes of round-nosed chisels are of the general shape of the cape chisel with one edge rounded, making a convex cutting edge. Large round bottomed channels and all concave surfaces are the proper work of the round-nosed chisel.

All the accompanying forms should be made from a good grade of tool steel, carefully forged, hardened, and tempered to a purple color. The stock generally used is octagonal, and the chisels for heavy work are about eight inches long and three-quarters of an inch in diameter.

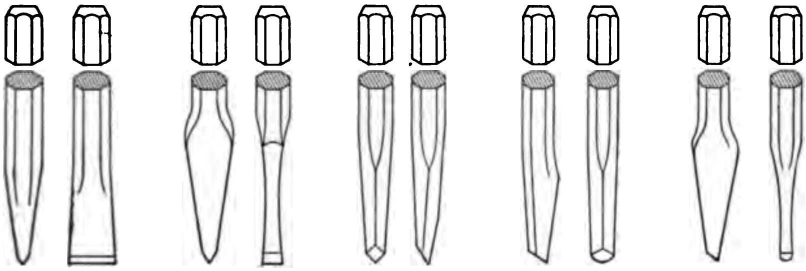


Fig. 44.

The two bevels forming the cutting edge of a chisel should make with each other as small an angle as is possible without leaving the cutting edge weak. If the angle is too small, the chisel will soon become dull, while if large, more force will be required to drive it. The best angle for cutting cast iron, all things considered, is about 70°, while for wrought iron and mild steel a slightly smaller angle, say 60°, will be better. When there are two bevels, they should be alike in width, and form equal angles with the center line of the chisel. Small round-nosed chisels and some slotting chisels are ground one-sided, that is, with but one bevel like a wood chisel. The angle between the surfaces which form the cutting edge should be the same, whether these surfaces are both bevels, or one a bevel and the other the straight side of the chisel. In a one-sided chisel, therefore, the angle that the bevel forms with the center line of the chisel should be twice as large as in one having two bevels.

To cut well, chisels should be sharp, and therefore should be ground at once when they become dull. This may be done on an emery or carborundum wheel, not finer than No. 60, care being taken to avoid heating, which draws the temper, and spoils the tool.

Chipping is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies. The piece is held in a vise, and the method of working is to grasp the chisel firmly with the left hand, holding the cutting edge to the work, and striking the head of the chisel with the hammer, keeping the eyes on the edge of the chisel to watch the progress of the work (see Fig. 45). The lower side or bevel of the chisel is the guiding surface, and is held at a very slight angle with the finished portion of the work, the cutting edge only touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel, and causes the chisel to take a heavier or lighter cut. If the hand is carried too low, the chisel will run out before the end of the cut; while if the hand is raised too high, the progress will be slow, owing to the resistance offered by the metal to separation. The depth of the cut taken with a cold chisel should never be more than an eighth of an inch.

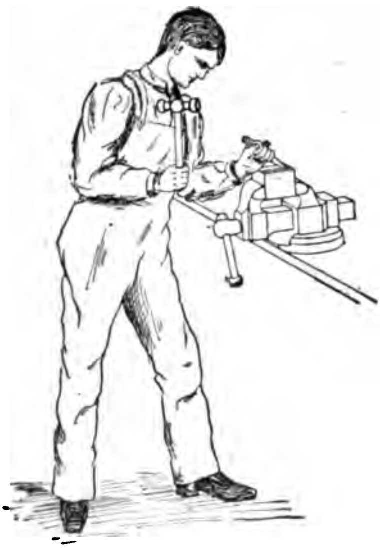
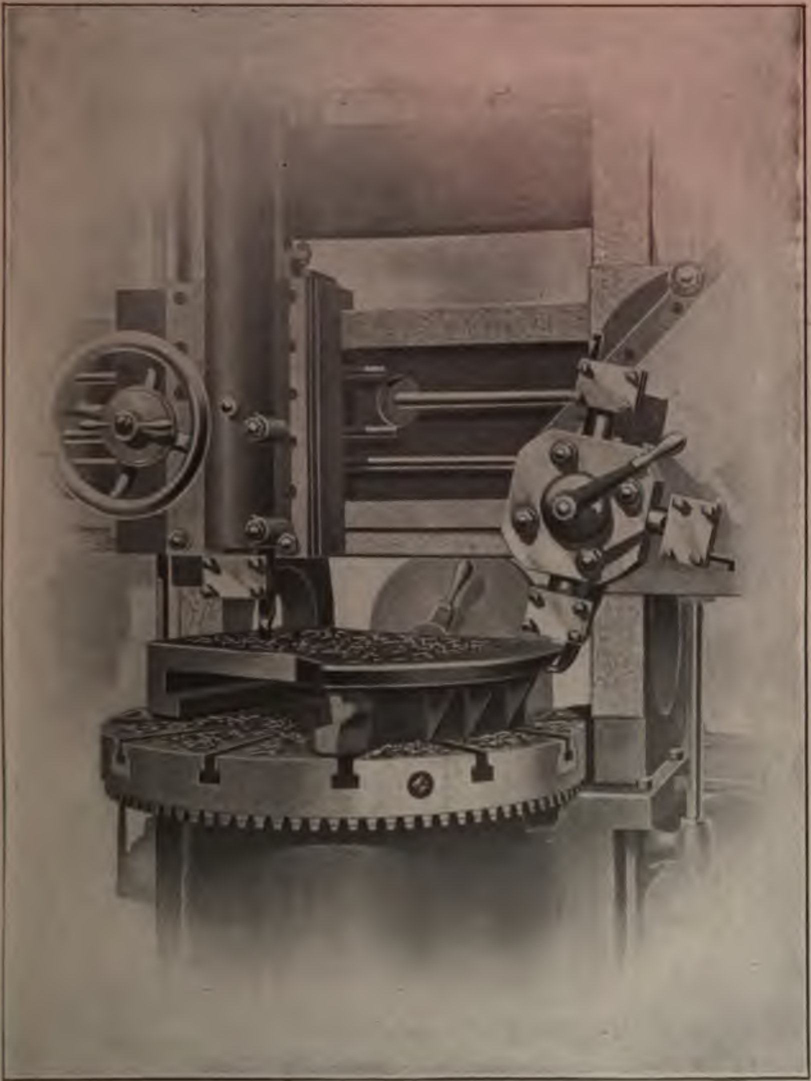


Fig. 45.

When chipping wrought iron or steel, a piece of waste saturated with oil should be kept on the bench, and the edge of the chisel frequently thrust into it. This lubricates the surfaces in contact and preserves the cutting edge of the chisel. While lines are used as guides in chipping operations, it is never advisable to bring the surfaces too near them with the chisel; sufficient stock must be left so that the surfaces may be finished with a file. This



BORING AND TURNING MILL.

Turning Bevel with Swivel Head.

Bullard Machine Tool Co.

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is especially to be observed in chipping key ways with a cape chisel; an ample margin for filing should be left, both on the sides and on the bottom.

The **file** differs from the chisel in having a large number of cutting points instead of one cutting edge, and in being driven directly by the hand instead of by the hammer. As hand power only is used, it is evident that the amount of metal removed at one stroke will be small, and the amount removed by a single tooth will be exceedingly small.

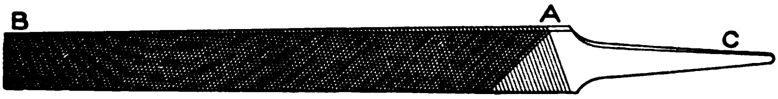


Fig. 46.

Files are made from cast or crucible steel, and in manufacture pass through the successive processes of forging, annealing, grinding, cutting, hardening, and tempering. They have three distinguishing features, viz., length, kind or name, and cut or coarseness of teeth. Length is measured from the heel A to the point B, Fig. 46; the tang C not being included. These lengths vary from three inches to twenty inches.

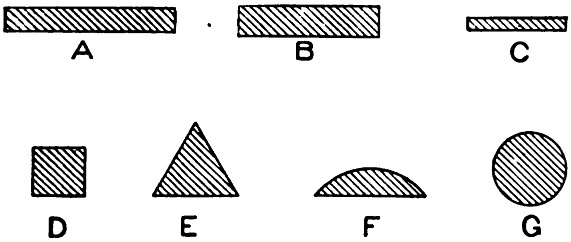


Fig. 47.

There are many kinds manufactured, those in common use being the flat (A), hand (B), warding (C), square (D), three square or triangular (E), half round (F), and round (G), sections of which are shown in Fig. 47.

The cut of files is in two styles, single and double; and each style has several grades of coarseness, viz., coarse, bastard, second-cut, smooth, and dead smooth. The last two grades are sometimes called fine and superfine. As is shown in Fig. 48, the coarseness of each style varies with the length — the longer the file the coarser the cut.

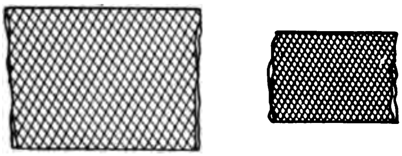


Fig. 48.

If the cutting surface of a file were perfectly flat, the number of teeth or cutting points engaged with the work would depend on the width of the file and the width of the piece being filed. To force as many cutting points as would be contained in such a large area deeply enough into the metal to enable each to remove its share of the stock, would be beyond the power of the man pushing the file. To avoid this necessity for great pressure, files are usually "bellied" or made slightly convex in the direction of their length, so that, theoretically, the file and the work are in contact only on a line as long as the width of the file. This enables the file to be forced into the metal sufficiently for the teeth to bite, and thus avoids dulling the teeth, which always occurs when the file is allowed to glide over the work without sufficient cutting.

This convexity of files also serves another purpose. The pressure applied to the file to make it bite bends the file more or less (see Fig. 49), and if the file in its natural state were perfectly flat, when cutting it would be concave; and this would prevent the production of a flat surface. It would cut away at the edges of the work and leave a convex surface. Such files might, however, be used on convex surfaces.

Work for filing is usually held in a vise such as has already been described, and under ordinary circumstances the surface of the work should be about the height of the elbow. For fine work with small files, where close observation is of more importance than pressure on the file, the work should be higher than this, the height increasing with the refinement of the work. On the other hand, for very heavy filing, where great pressure is absolutely necessary, the work should be several inches below the point of the elbow, so that the weight of the body may be used to good advantage, and also because the workman naturally stoops a little when exerting great pressure on the file.

The handles commonly attached to files are made of wood and are made to fit the hollow of the hand. They are driven onto the tang of the file; a ferrule on the handle preventing it from splitting. Care should be taken to have the axis of the handle parallel with the file. A good way to prepare the handle for the tang is to heat the tang to a dull red, the file proper being kept cool by a piece of wet waste, and the hole in the handle burned cut until the tang is almost in the position it is designed to finally occupy. After cooling the tang, very little driving will be required to securely fasten the handle to the file.

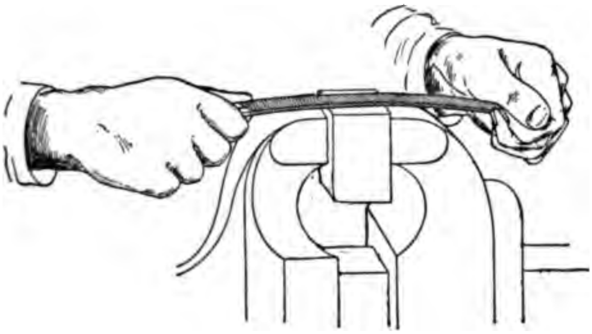


Fig. 49.

When filing surfaces of such size that the handle as ordinarily applied would interfere with the use of the file, the tang may be bent up to an angle so that the handle will clear the surface. Various forms of holders are used for filing under these circumstances; the simplest forms being shown in Fig. 50.

The correct position for filing is about as follows: feet about eight inches apart and at right angles, the left foot being in line with the file; stand back from the vise so that the body may follow the file slightly; grasp the file handle with the right hand, fingers below, thumb on top of the handle; for coarse filing, place the ball of the thumb of the left hand on the point of the file; for fine filing grasp the point of the file with the thumb and forefinger of the left hand. See Fig. 51. When holding the file in one hand, as is often done in light work, the forefinger should be on top of the file pointing in the direction of its length, as is shown in Fig. 52. This allows free movement of the hand and wrist, pressure being applied principally by the forefinger.

As file teeth or cutting edges point toward the end of the file, it is evident that the file can cut only when moving in a forward direction. On the return stroke, the pressure should be relieved; otherwise the teeth will be dulled when drawn back over the surface.

The kind of metal being worked determines in a great measure the character of the file to be used. Cast iron, especially if the scale has not been previously removed, is particularly hard on a new file, as the glassy character of the scale tends to dull the cutting edges. New files should never be used on such a surface. It is found that on tool steel, and hard materials generally, a second-cut file is better than the bastard. This is because if pressure enough is exerted to cause the coarse teeth of the bastard to bite into the work, the teeth, being comparatively long, are very likely to be broken off. In the second-cut file, the teeth are shorter and present more cutting points in a given area; thus preventing excessive duty being imposed on a few teeth.

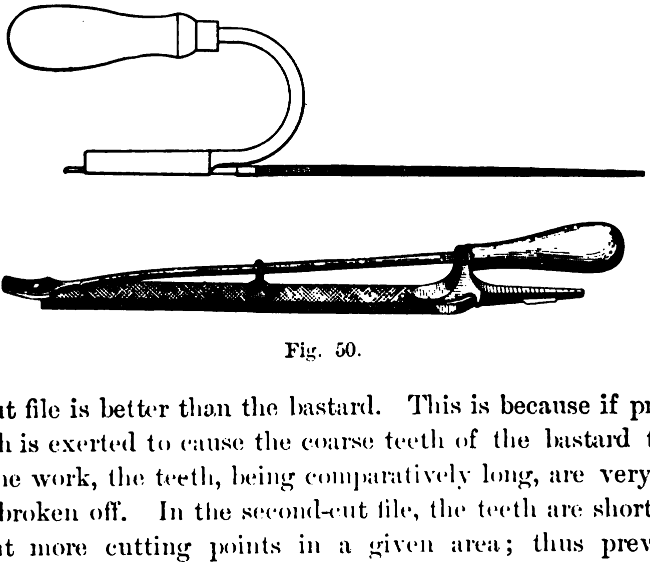


Fig. 50.

Softer metals, such as brass and bronze, allow the use of the coarser grades.

The particles of metal removed by a file frequently remain in the teeth and diminish their cutting qualities. In the case of hard metals these particles, or "pins," often scratch the work. It is necessary, therefore, that files be frequently cleaned. This may be done in a measure by striking the edge of the file lightly against the bench or vise, but it is more effectually performed by using a stiff brush or a piece of card clothing (Fig. 53). In the finest grades of files, a thin piece of wood or sheet brass may be drawn across the surface of the file as shown in Fig. 54, and the filings are removed by the points extending into the file teeth.

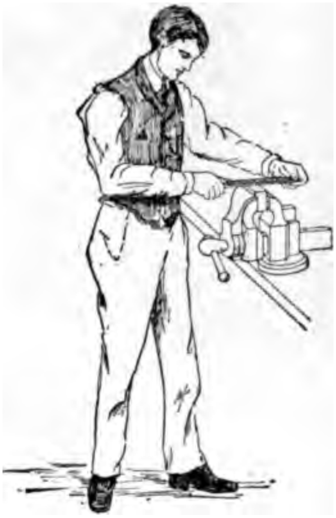


Fig. 51.

When filing cast iron, neither the file nor the work should be allowed to become greasy, as this tends to make the file slide without cutting. In filing steel, however, if the file be oiled or filled with chalk, the pinning of the file is prevented in a large degree, and frequent use of the card or brush is not necessary.

What is known as drawfiling is done by grasping the file at each end and moving it sidewise across the work. (See Fig. 55.) The amount of stock removed by this process is usually very small, the object being to lay the file-marks parallel to the length of the work. Single-cut files are better than double-cut for this purpose, being less likely to scratch the work. The remarks concerning cleaning, oiling, and chalking apply both to cross-filing and draw-filing.

No matter how carefully filing is done, it does not leave a surface that is pleasing to the eye; the file-marks are more or less irregular and the whole surface is dull. Exposed parts of machines which are not painted are usually polished. Polishing

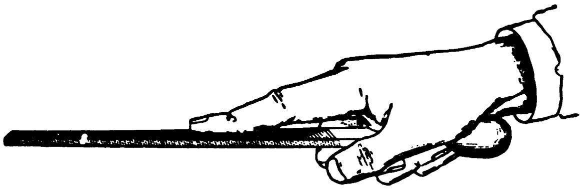


Fig. 52.

does not improve the surface, but simply brightens it and renders it more attractive. As a rule, a polished surface is not a true surface, no care being taken to maintain its truth. In ordinary machine work polishing is usually done by abrasives, such as emery, corundum, and carborundum, while rouge, crocus, rottenstone, and tripoli are used on fine work, especially on brass and composition. Emery, for example, is crushed and sorted into grades varying from No. 8 to flour, the number of the grade indicating the number of meshes per inch in the sieve used in sorting. These grades sometimes bear arbitrary designations, No. 1 indicating a coarse grade and No. 0, 00, 000, 0000 showing the finer grades. These powders are sometimes mixed with oil and applied directly to the work by wooden blocks or clamps; but the more common method is to use what is known as emery cloth, the grains being glued to a strong cloth backing. The finer grades are used on paper in the same manner.

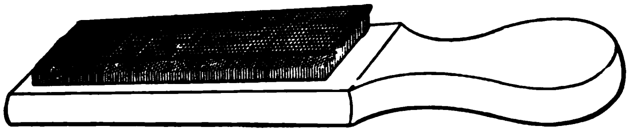


Fig. 53.

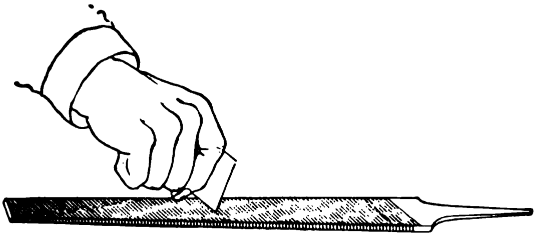


Fig. 54.

Emery cloth is used in many ways; it may be wrapped around a file; folded or tacked to a block of wood; glued to wooden sticks about 15 inches x 1½ inches x ½ inch, fastened around rollers for internal curves, or glued to wooden or steel disks and rotated in a lathe or special machine. In all cases the object is to grind down the surface, using a sufficient number of grades of cloth to produce the degree of polish desired. The marks are laid parallel to each other, making what is known as a "grain." When the process is to be carried to such an extent that no grain is to be visible, the finer polishing agents are used, usually applied with a cloth wheel or "lap." Old cloth does finer work than new, and oil on the cloth will make a finer cut.

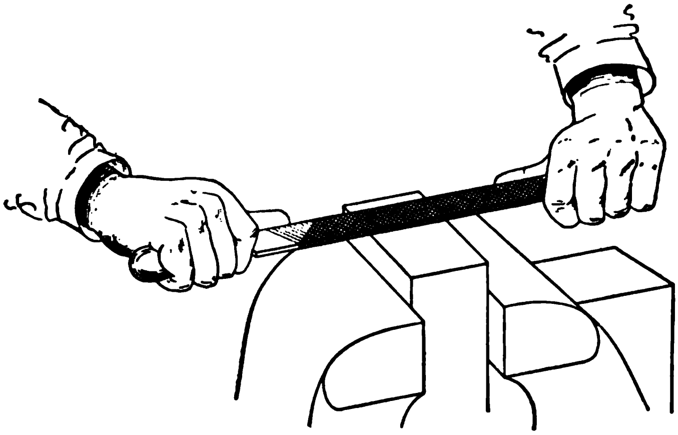


Fig. 55.

Scraping. When two flat or curved surfaces are to be worked together, and complete contact over the whole or both is desired, they are scraped. Scraping removes less metal than filing, and also enables the workman to confine the removal to limited areas. The scraper should be made from a very close-grained tool steel, and is nearly two feet long exclusive of the handle. The general shape is shown in Fig. 56. The cutting edge is about $\frac{3}{32}$ of an inch thick and $1\frac{1}{2}$ inches wide. It is ground on an emery wheel and grindstone, and carefully oilstoned, leaving the cutting edge as straight as possible. Scrapers are sometimes made from old files, the teeth being ground off and the end drawn out wide and thin. Sometimes the end is bent at right angles to the shank, as shown in Fig. 57. The cutting done by scrapers should be perfectly smooth and free from scratches.

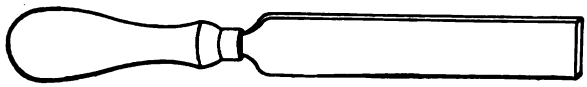


Fig. 56.

In using the surface plate as a test for the truth of a plane, such as a valve or its seat, the plate is covered with a very thin coating of red lead and then rubbed over the valve or seat. The latter should have previously been finished as smoothly as possible. The spots where the red lead shows contact are scraped off, and the process continued until contact over the entire surface is obtained. During the last part of the operation alcohol should be used instead of red lead, as it leaves clean bright spots to indicate where the scraper must be applied. Small pieces of work are rubbed over the surface plate, and in any case care should be taken to distribute the wear uniformly over the plate in order to prolong the truth of the plane. The scraper for concave surfaces, such as boxes, is of the general shape of a half-round file without teeth. In such cases, the shaft to be used takes the place of a surface plate. The method of holding and using such a scraper is shown in Fig. 58.

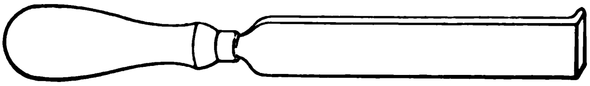


Fig. 57.

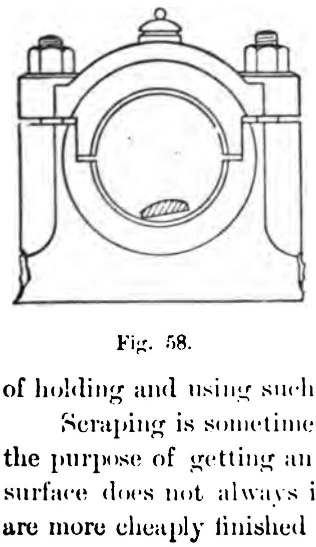


Fig. 58.

Scraping is sometimes done as a matter of finish, and not for the purpose of getting an accurate surface. Therefore, a scraped surface does not always indicate accuracy. Many machine parts are more cheaply finished by scraping than by polishing.

DRILLS.

Drills are of two general classes, the flat and the twist. A **flat** drill of a common type is shown in Fig 59. The angle between the two cutting edges should be about 110°. These drills are usually made from round tool steel drawn out wide and thin, as shown; the undressed end being used for holding. The flat drill is usually made in the shop where it is to be used. Its low first cost is the principal reason for its existence.

Flat drills made from thin flat stock are used in connection with a slotted rest to start and drill holes in the lathe without previous centering. They are called **chuck-drills.** The end of the shank of the drill is provided with a center hole to receive the dead center of the machine. The drill and rest are shown in Fig. 60.

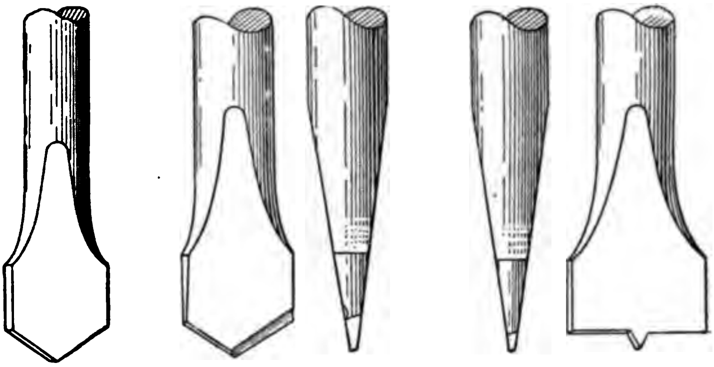


Fig. 59.

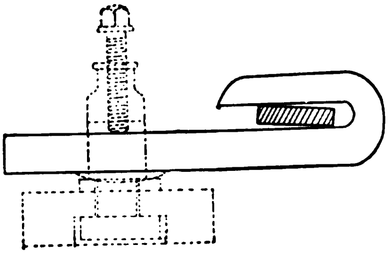


Fig. 60.

The simplest form of **twist drill** is cylindrical throughout its entire length, as shown in Fig. 61, and has two spiral flutes which at the end serve to form the cutting lips, and which also serve to carry the chips from the hole. The included angle of the lips is 118°. This form of drill will work more accurately than the flat drill, as the cylindrical portion serves as a guide to keep the cutting lips in their proper position. The edge being somewhat hooking, removes the metal by a cutting instead of a scraping action as in the flat drill. This form of drill cannot only be fed faster, but can be forced into the work with less power, as it has a tendency, especially noticeable in soft metals, to feed itself into the work. Straight shank twist drills are made from

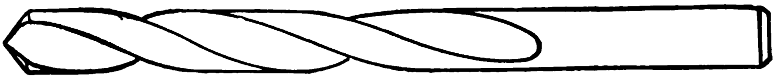


Fig. 61.

.0135 inch to 2½ inches in diameter; the smaller sizes are sold in sets designated by numbers (1 to 80), letters (A to Z) or fractional sizes (½ inch to $\frac{1}{16}$ inch).

The *taper-shank twist drill* is shown in Fig. 62. It consists of a body A, which is fluted and does the actual work, and a taper shank B, by which it is held. This taper fits accurately into the spindle or chuck of the drill press. At the end there is a tongue C, which slips into the key way in the spindle or chuck. As this surface is flat, it serves as a bearing by which the drill is driven. This relieves the tapered portion from the stress of driving by frictional resistance alone. For small drills this frictional resistance is sufficient, but for larger sizes it will not do at all. If for any reason the tongue should become broken, no dependence should be placed upon the frictional resistance of the taper shank to drive the drill. The drill will slip and wear the socket, which will become enlarged and make a misfit for other drills.

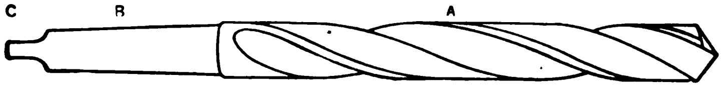


Fig. 62.

The **standard taper** for drill shanks may be considered to be what is known as the Morse. This taper is $\frac{5}{8}$ inch to the foot. There is another known as the Brown & Sharpe or Jarno which has a taper of $\frac{6}{10}$ inch to the foot. No attempt should be made to run the drills of one taper in the sockets of the other.

A flat taper key, introduced into the key way, engages the end of the tongue and serves to remove the drill from the spindle.

Drills of cylindrical form are also made with straight flutes as shown in Fig. 63. They are used for drilling soft metals, such as brass, especially when the drill passes entirely through the piece. As it breaks through the metal, a drill with spiral flutes tends to draw itself through rapidly, as if it were a screw working in a nut. This may break the drill or move the work from position. Straight flutes give the same cutting action as a flat drill and avoid this tendency to draw.

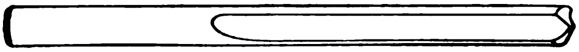


Fig. 63.

Lubrication of Drills. When drilling tough metals such as steel, wrought and malleable iron, heat is generated by the bending or changing of the form of the metal being removed and by friction caused by the chips moving over the lips of the drill. The heating is similar to the heating of a piece of wire bent quickly back and forth. As there is danger of heating the drill to a temperature that will draw the temper and soften the drill, plenty of lard oil, or a mixture of potash and water, should be used. This is not so much for lubrication as to remove the heat.

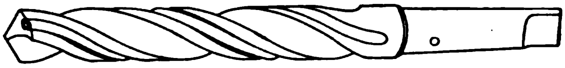


Fig. 64.

Copper is the most difficult to drill of all the common metals on account of its extreme toughness; then, too, copper heats to a higher temperature on account of its low specific heat. Brass does not require the use of oil, and cast iron must always be drilled dry. Particular attention is called to this precaution regarding cast iron.

As the heat is produced at the point of the drill, it is desirable, particularly in the case of deep holes, that the oil be applied directly at the drill point. For this purpose, oil-tube drills, such as is shown in Fig. 64, are used.

The oil is supplied under pressure, and not only removes the heat, but also carries away the chips.

Speed of Drills. The speed at which drills should be rotated depends on the diameter of the drill and the material operated upon. No absolute rule can be given for any one metal or diameter of drill, because of the variation in hardness and tenacity of the material and the condition of the cutting edge of the drill.

The following table of revolutions per minute, given by the Cleveland Twist Drill Co., is based on a peripheral speed of 30 feet a minute for mild steel, 35 feet per minute for iron, and 60 feet per minute for brass.

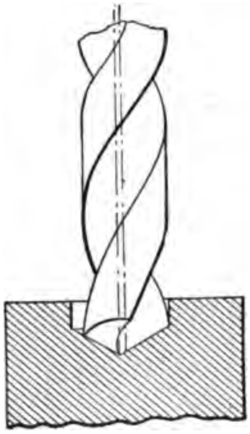


Fig. 65.

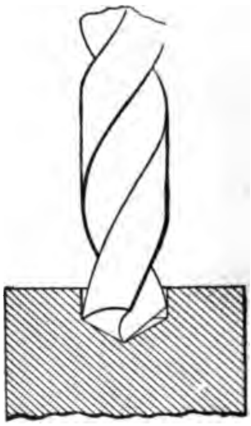
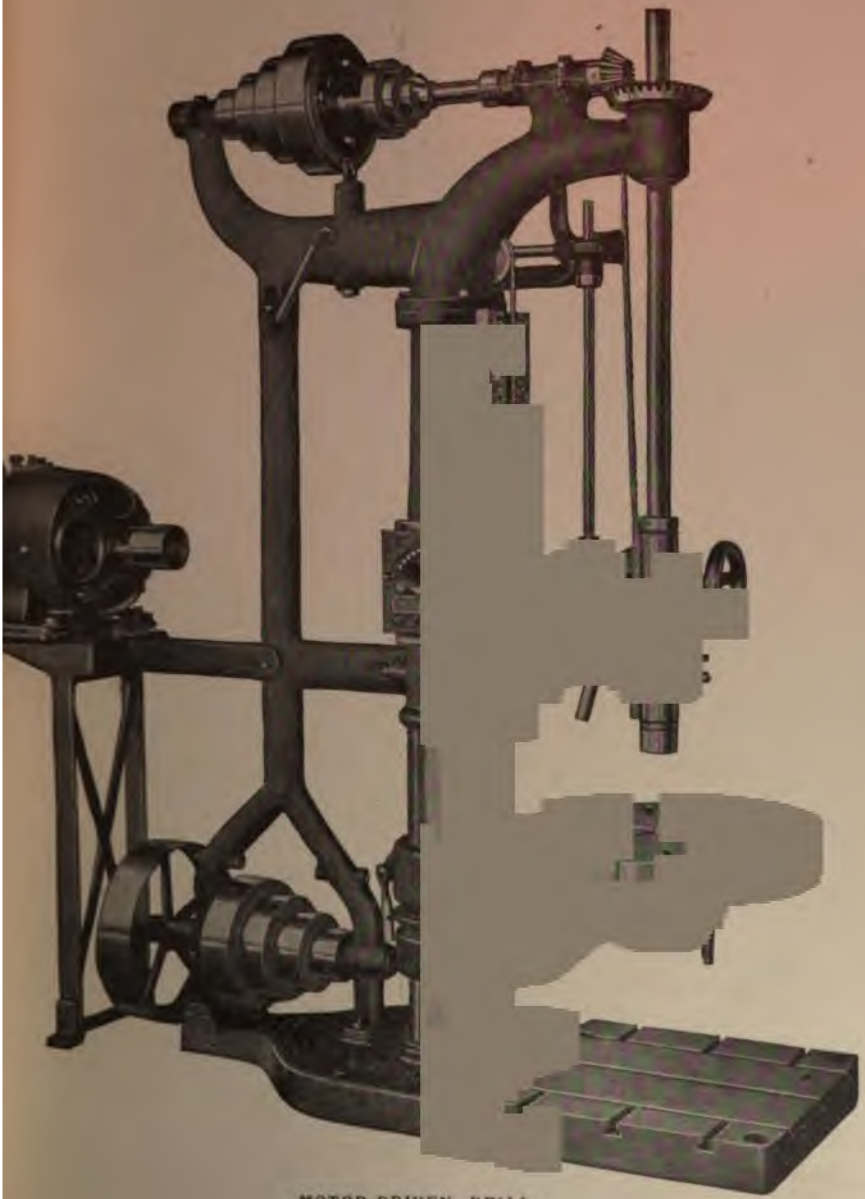


Fig. 66.

The rate of feed also depends on the drill diameter and the material. The above mentioned authority gives, as a maximum, one inch of feed for 95 to 125 revolutions.

Grinding Drills. Great care should be exercised in the grinding of drills. The end of a drill should be symmetrical; that is, the lips should be of the same length, and form the same angle with the axis. If the lips are of unequal length, the hole will be larger than the drill, as is shown in Fig. 65. The point is not in the axis, and the hole will not only be large but also will not be parallel to the drill spindle. If the lips do not form equal angles with the axis, all the cutting will devolve upon the one making the greater angle as shown in Fig. 66. Such a drill will not cut as fast as, and will become dull sooner than, one which is properly ground.



MOTOR-DRIVEN DRILL.

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Hand-grinding, especially of twist drills, is neither accurate nor satisfactory; it is much better to do such work on a regular drill grinder built especially for the purpose.

SPEED OF DRILLS.

Diameter of Drill.	Speed for Soft Steel or Wrought Iron.	Speed for Cast Iron.	Speed for Brass.
$\frac{1}{16}$	1824	2128	3648
$\frac{1}{8}$	912	1064	1824
$\frac{3}{16}$	608	710	1216
$\frac{1}{4}$	456	532	912
$\frac{5}{16}$	365	425	730
$\frac{3}{8}$	304	355	608
$\frac{7}{16}$	260	304	520
$\frac{1}{2}$	228	266	456
$\frac{9}{16}$	203	236	405
$\frac{5}{8}$	182	213	365
$\frac{11}{16}$	166	194	332
$\frac{3}{4}$	152	177	304
$\frac{13}{16}$	140	164	280
$\frac{7}{8}$	130	152	260
$\frac{15}{16}$	122	142	243
1	114	133	228
$1\frac{1}{16}$	108	125	215
$1\frac{1}{8}$	102	118	203
$1\frac{3}{16}$	96	112	192
$1\frac{1}{4}$	91	106	182
$1\frac{5}{16}$	87	101	174
$1\frac{3}{8}$	83	97	165
$1\frac{7}{16}$	80	93	159
$1\frac{1}{2}$	76	89	152
$1\frac{9}{16}$	73	85	145
$1\frac{5}{8}$	70	82	140
$1\frac{11}{16}$	68	79	135
$1\frac{3}{4}$	65	76	130
$1\frac{13}{16}$	63	73	125
$1\frac{7}{8}$	60	71	122
$1\frac{15}{16}$	59	69	118
2	57	67	114

While grinding, care must always be exercised that the cutting edge is not overheated on the stone or emery wheel. If it is overheated, the temper will be drawn and the drill become too

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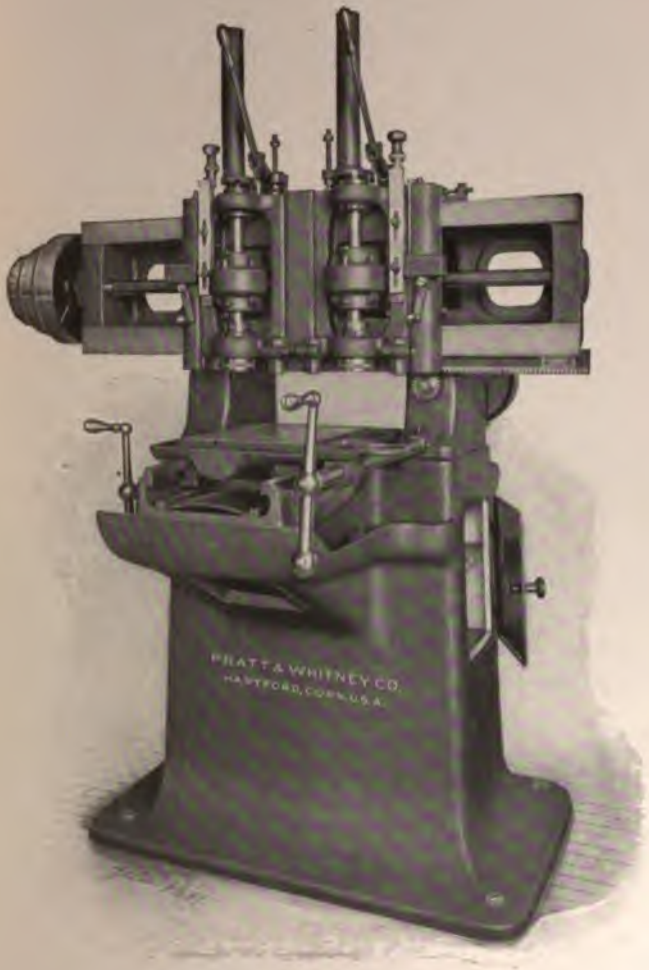

TWO-SPINDLE PROFILING MACHINE.
Pratt and Whitney Co.

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In reaming cored holes, the cylindrical chuck reamer, sometimes called the roughing reamer, is often used. It is made either rose, Fig. 70, fluted, or with three spiral flutes, Fig. 71, and generally have solid shanks. The last-named style will finish very smooth and close to size when started true by preliminary boring.

A solid reamer cannot be sharpened without reducing its diameter; therefore, it must be used carefully in order to prolong its life. Reamers with adjustable blades meet this objection, but cost much more than the solid form. An expanding reamer, Fig. 72, can be slightly enlarged to compensate for grinding, and is then used as a solid reamer. Fig. 73 shows an adjustable reamer with inserted teeth.

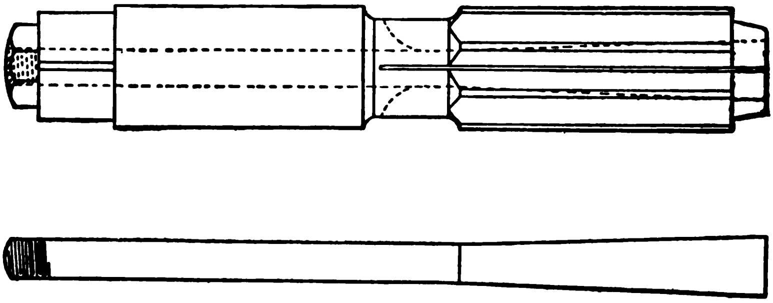

Fig. 72.

Reamers are made for tapered as well as for straight holes. The angle varies with the intended use of the taper; for example, the *locomotive taper* of $\frac{1}{16}$ inch per foot is intended for bolt holes where plates are to be drawn solidly together and the holes completely filled. It is very difficult to remove a bolt from a hole with such a slight taper. When pieces are pinned together, such

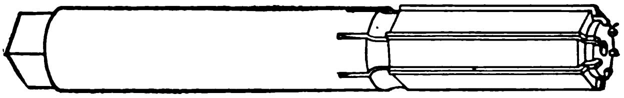

Fig. 73.

as a hub to a shaft, it is intended that they can be separated when desired, so the taper is made steeper, generally $\frac{1}{4}$ inch per foot. This has come to be known as the *pin taper*. Taper holes for holding lathe centers and taper shank twist drills are generally made $\frac{5}{8}$ inch per foot (*the Morse taper*). This angle holds the tool firmly, and still it can be easily removed. The three tapers mentioned are recognized as standard, and reamers for them are carried in stock. Of course many other tapers are used by different manufacturers, but they are regarded as special. Fig 74 shows taper reamers.

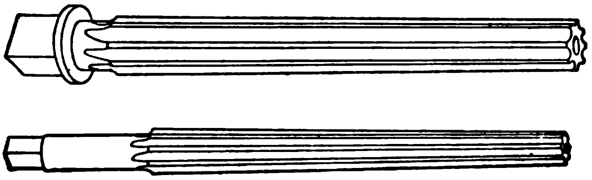

Fig. 74.

Taper reamers differ from hand reamers only in the angle and by not requiring the tapered entering end.

Holes to be reamed by taper reamers must be slightly larger than the small end of the reamer; and, if the hole is deep, it is usual to make a stepped hole, shown exaggerated in Fig. 75, by using drills of different diameters.

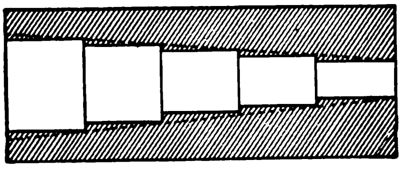

Fig. 75.

When not carefully sharpened, all forms of reamers have a tendency to chatter and produce rough surfaces. To avoid this, the flutes are frequently irregularly spaced; another method is to use spiral flutes, usually left hand.

TAPS.

When internal thread cutting is done, the tool is called a tap. There are many styles of taps; the names in some cases are suggested from the shape, but more often from the use. In most machine shops are found the following forms: hand, machine screw, pipe, pulley, stay-bolt, boiler, and tapper; of these the hand and machine screw are the most common. The object of all is to make spiral grooves, called threads, in holes, so that they may receive and hold screws, bolts, studs, etc.

As the size of a tap is the diameter outside the threads, it is evident that the hole drilled for tapping must be smaller than the tap by nearly, if not quite, twice the depth of the thread. The shape of the thread partly determines the amount to be subtracted from a tap diameter. There are now recognized as standard, five different threads, viz.: sharp or V, Franklin Institute or United States standard, Whitworth, International or metric, and the 29° or Acme. These shapes will be described and compared under Screw Cutting. The following table shows the diameters of the holes that are to be drilled for cutting the various sizes of the threads according to the United States standard and the ordinary V-thread.

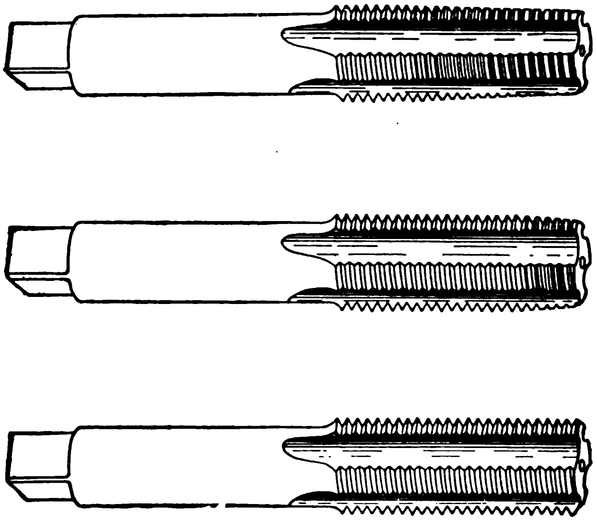

Fig. 76.

Hand taps are most commonly used in shop practice, and a description of the operation will answer for all styles. They are usually sold in sets of three, —taper, plug, and bottoming. See Fig. 76.

The cutting of a thread with a tap is not difficult, but requires care in the manipulation. The tap does not need to be forced into the work, since the thread will draw it forward. The tapering of the tap has a two-fold effect. No one thread must do all of the work in the removal of the metal; each succeeding thread removes a small amount until the full thread has entered the hole. The second effect is that, as in the cases of a reamer, the tap is easily entered and started. Care must always be exercised at this point of the work. The taper of the tap allows it to easily enter the hole, and also makes it possible for it to enter at an angle. If

TABLE OF TAPS AND CORRESPONDING DRILLS.

Tap. Diameter in Inches.	No. Threads per Inch.	U.S. Standard Drill Diameter.	V-Thread Drill Diameter.	Tap. Diameter in Inches.	No. Threads per Inch.	U.S. Standard Drill Diameter.	V-Thread Drill Diameter.
1/4	20	3/16	11/64	1 7/8	5	1 5/8	1 17/32
5/16	18	1/4	15/64	2	4 1/2	1 23/33	1 21/32
3/8	16	9/32	9/32	2 1/4	4 1/2	1 31/32	1 7/8
7/16	14	11/32	21/64	2 1/2	4	2 3/16	2 3/32
1/2	13	13/32	25/64	2 3/4	4	2 7/16	2 11/32
9/16	12	7/16	7/16	3	3 1/2	2 5/8	2 1/2
5/8	11	1/2	1/2	3 1/4	2 1/2	2 7/8	2 3/4
11/16	11	9/16	9/16	3 1/2	3 1/4	3 1/8	2 15/16
3/4	10	5/8	19/32	3 3/4	3	3 5/16	3 3/16
13/16	10	21/32	21/32	4	3	3 9/16	3 7/16
7/8	9	23/32	45/64	4 1/4	2 7/8	3 13/16	3 11/16
15/16	9	3/4	49/64	4 1/2	2 3/4	4	3 7/8
1	8	27/32	13/16	4 3/4	2 5/8	4 1/4	4 1/16
1 1/8	7	15/16	29/32	5	2 1/2	4 1/2	4 1/4
1 1/4	7	1 1/16	1 1/32	5 1/4	2 1/2	4 3/4	4 1/2
1 3/8	6	1 5/32	1 1/8	5 1/2	2 3/8	5	4 3/4
1 1/2	6	1 9/32	1 15/64	5 3/4	2 3/8	5 1/4	5
1 5/8	5 1/2	1 3/8	1 5/16	6	2 1/4	5 1/2	5 1/4
1 3/4	5	1 1/2	1 13/32				

it is started in the latter condition, the thread will not be at right angles to the surface. The degree of care needed in the starting of the tap depends upon the job that is to be done. In the case of tapping a nut, it will usually be quite sufficient to set the tap by the eye. In finer classes of work, however, the tap should be set with a square. Start the tap into the hole, and place a square on the surface beside it in two positions at right angles to each other, and see that the tap stands parallel to the vertical blade.

When holes have been drilled that are to be tapped, a good way of setting the tap is to put a center in the drill spindle. Put the tap into the hole, and bring this center down into the center hole in the head of the tap; this will steady the latter while it is being started.

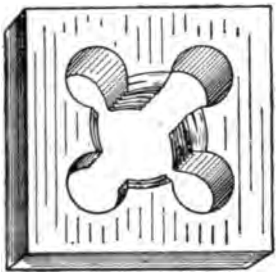
Fig. 77.

In using the tap, it is well to work it back and forth. This allows the chips to work clear of the cutting edges, and the oil to cover them. In case of heavy work, it is possible to drive the tap with the drill spindle, but when thus driving a tap in a machine, the backing up is impossible.

Sometimes a thread is to be cut down to the bottom of a hole that does not pass entirely through the metal. In this case the bottoming tap is used. This is a tap that is not tapered at the entering end. The method of working is to first cut the thread as far as possible with the plug tap, and then use the bottoming tap, which will then enter easily and can be driven to the bottom.

Machine tapping is best done by using a frictional tap-holder; that is, one in which the friction is enough to cut the threads, but which will slip when the tap strikes the bottom of the hole. This will insure the hole being tapped to the bottom, and avoid all danger of breaking the tap. To withdraw the tap, the machine is reversed, usually at a higher speed than used in tapping.

When tapping wrought iron and steel, a plentiful supply of oil should be used. On brass the use of oil is unnecessary, while cast iron should always be tapped dry.

DIES.

Dies are used for cutting threads on bolts and other similar parts to be placed in holes which have been threaded by taps.

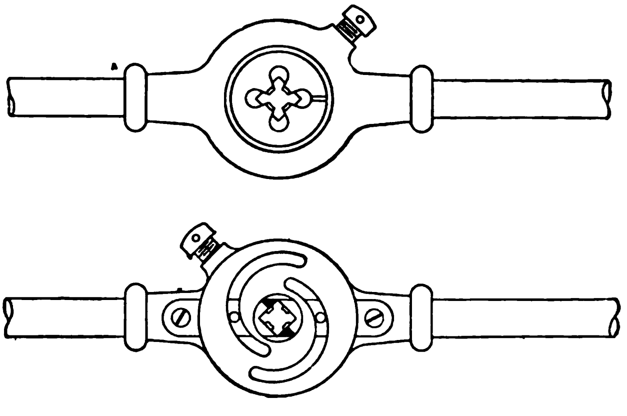

Fig. 78.

The general rules given for the use of taps apply to dies. As the number of threads in a die is much less than on a tap, and because the chips have a much freer exit, it is not as necessary to back up a die as it is a tap.

Dies for small work are usually made solid, as shown in Fig. 77, and often have a slight adjustment for altering the size. They cannot be sharpened, but have an advantage in readily centering on the work. As the full thread is cut at one passage of the die, it takes considerable power to operate solid dies of large size. For this reason, hand-operated solid dies are seldom used above one-half inch. The holder or die stock shown

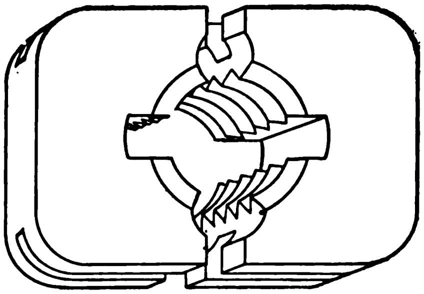

Fig. 79.

in Fig. 78 has a guide to hold the work at right angles to the die, but die stocks are often made without this convenience.

The split form of die, generally known as the jamb-die (shown in Fig. 79), can be easily sharpened, has unlimited adjustment for size, and cuts the thread by easy stages, as it were.

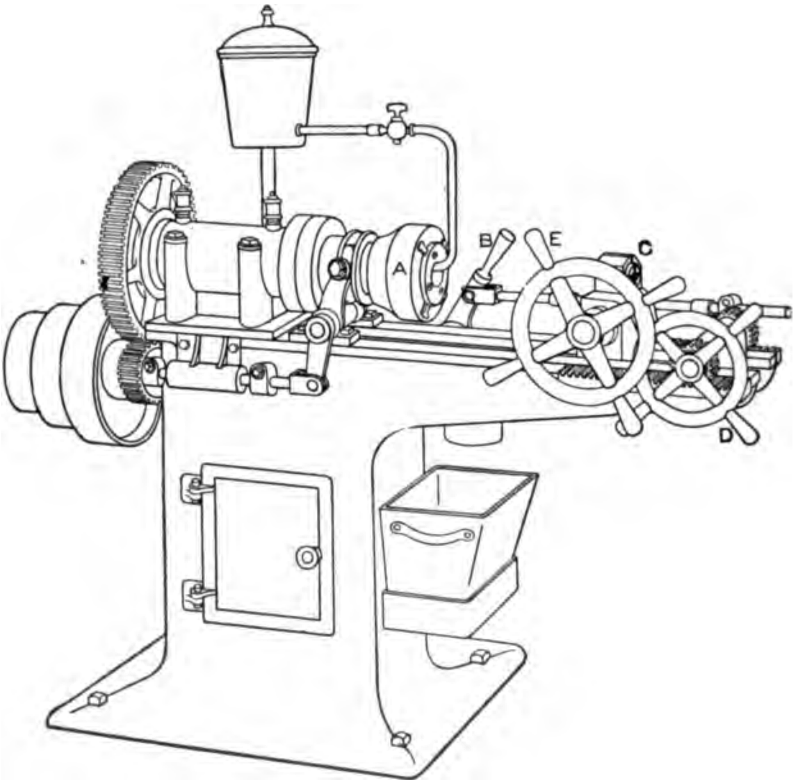

Fig. 81.

It is made in sizes up to two inches, and is for hand operation only. The holder for this form of die is called a screw plate, Fig. 80. These are not furnished with guides for the work.

Cutting Pipe Threads. Another common form of thread cutting is that on wrought-iron pipe. The pipe thread is rounded slightly at top and bottom, and is made tapering at the rate of three-quarters of an inch per foot. The dies are usually solid, square in form, and the die stocks are provided with a ring, which fits over the pipe and serves to hold it square with the die. This avoids the danger of cutting the thread at an angle with the pipe axis.

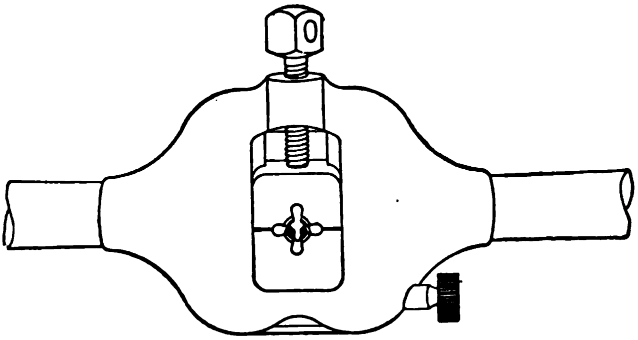

Fig. 80.

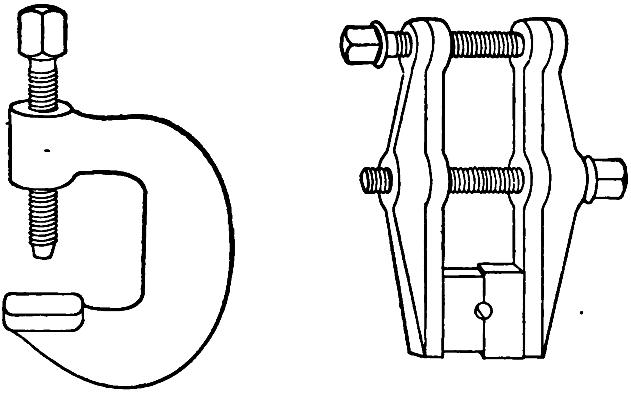

Fig. 82.

Comparatively little thread cutting is done by hand. A large proportion of all such work is performed on bolt-cutters. This is ordinarily the roughest and cheapest class of work, and the running of the bolt-cutter is usually the first work to which the apprentice is assigned.

Bolt-Cutter. An ordinary type of bolt-cutter is shown in Fig. 81. The dies are held in the head A. Instead of being solid, as in Fig. 77, they are made in sections, and can be opened or closed by the movement of the lever B. A chuck, C, is placed on a traveling head, and this can be moved back and forth by the hand-wheel D. The method of working is very simple. The dies in the head are closed in order to be in the working position. The bolt to be cut is gripped in the chuck by turning the handle E, and forced against the dies by the handle D. As soon as the dies have taken hold, they draw the bolt ahead. When a sufficient length of thread has been cut, the dies are opened and the bolt withdrawn. This avoids the necessity of backing out, as would be required if the dies were solid. While the thread is being cut, the dies are kept flooded with oil.

Templets. Where the same piece of work is to be many times repeated, templets are used. This method avoids the necessity of making measurements in the laying out of the work.

The *marking templet* consists of a piece of the same shape as the finished article. It is usually laid on a flat surface, and held fast by iron clamps as shown in Fig. 82. The outline is then marked on the surface with a scriber, and sometimes emphasized by prick punch marks.

The *filing templet* is of the same character as the one just described, but it is hardened. It is clamped in the vise with the piece to be shaped, and the surface filed down to coincide with the form of the templet.

Where holes are to be drilled in duplicate, a templet known as a *jig* is used. These jigs are made so that they fit over the piece to be drilled, and, when clamped in position, indicate the location of the holes by means of hardened steel bushings set in the templet.

The making of templets and jigs is one of the finest branches of the machinist's work, and is generally classed under the head of tool making. The rapid and economical production of machine parts in quantity depends largely on the tool maker, who must, therefore, be considered the highest type of machinist.

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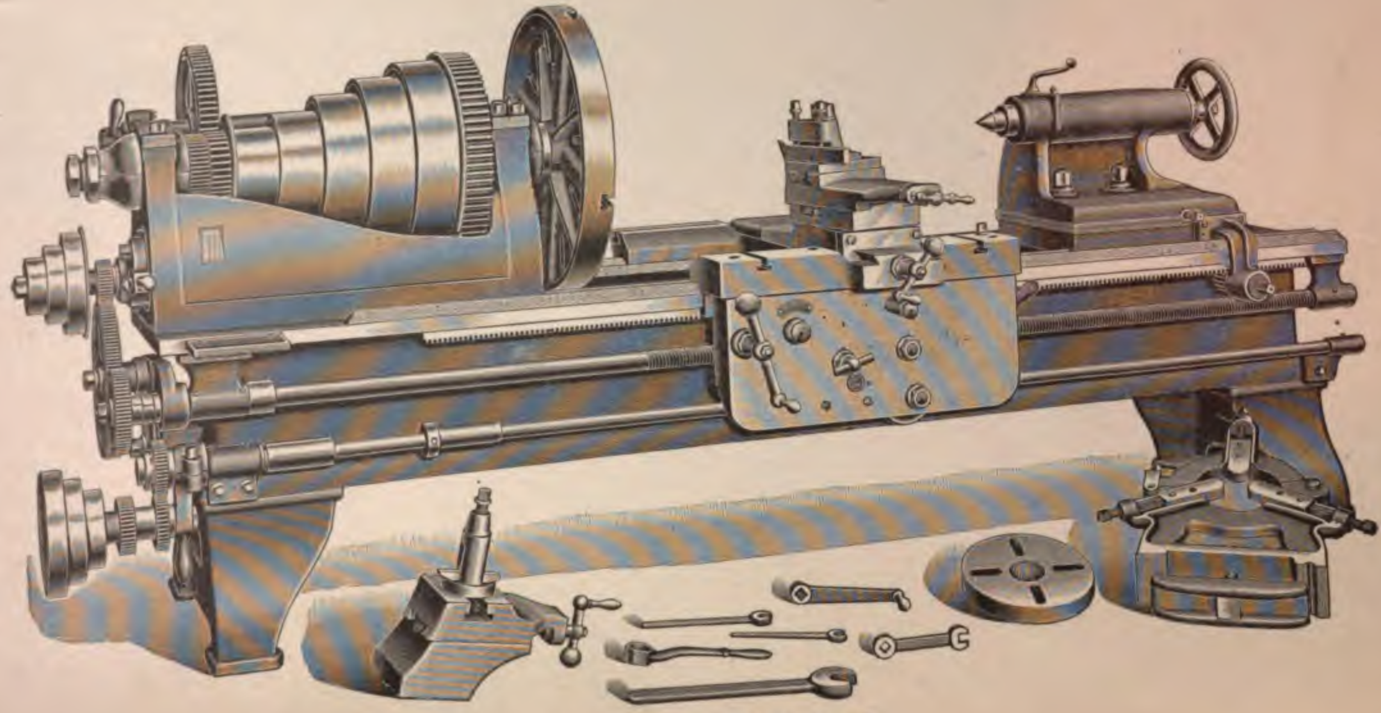


24-INCH SWING ENGINE LATHE.

F. E. Reed Company.

MACHINE SHOP WORK.

PART II.

THE LATHE.

THE lathe is one of the most ancient of tools, and is a development of the potter's wheel. The spindle is horizontal and the work is revolved while the cutting tool is stationary. In its various forms and sizes it is by far the most important tool in the machine shop. It is built in a wide range of sizes from the delicate instrument suitable for the work of the jeweler to the great machine capable of turning engine shafts for the largest ocean

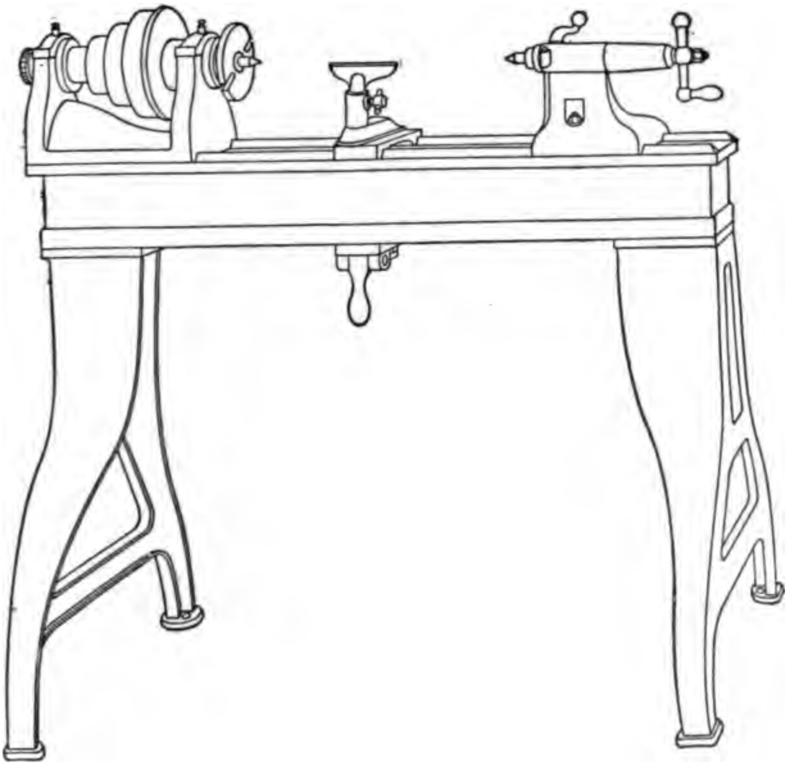
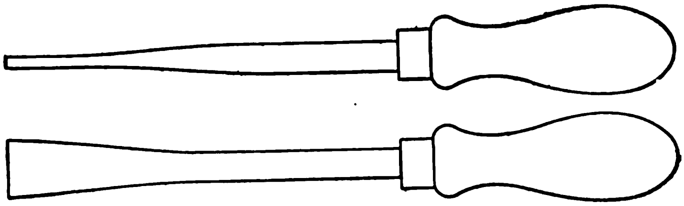


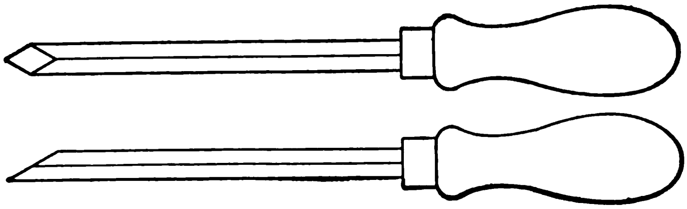
Fig. 83.

steamships or the rings for the heavy ordnance of battleships and fortifications.

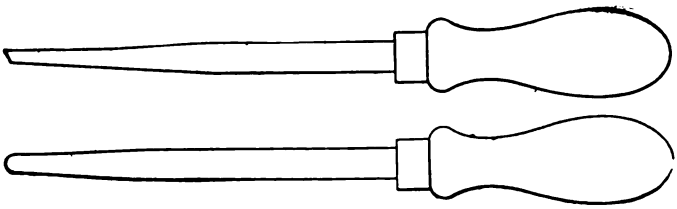
Speed Lathe. The small lathe used in the machine shop for the operations of hand turning, filing, and polishing is called the hand or speed lathe, Fig. 83. This type driven by foot power is in great favor with amateur workmen. While hand turning is avoided as much as possible, it cannot be wholly eliminated, and a brief description of the tools used and the operations performed seems necessary.



Planisher.



Graver.



Round Nose.

Fig. 84.

The tools used on brass and composition cut by a scraping action, and are almost always held at or below the center. The three tools shown in Fig. 84 called the planisher, graver, and round nose, are typical of all the tools necessary for turning brass, etc. The manner of holding these tools in connection with the T-rest is illustrated by the planisher in Fig. 85. Fig. 86 shows another view of the T-rest. Typical hand tools for cutting iron and steel are the diamond point or graver and the round nose, shown in Fig. 87. They are used differently from hand tools for brass, in that the cutting edge is carried above the center, and the metal is removed by cutting instead of scraping. The graver frequently takes the place of the planisher, for it can be used as shown in Fig. 88, either on the outside or on the end of a piece of work. The round nose is used solely for concave surfaces, being held as high on the work as proper cutting will allow; Fig.

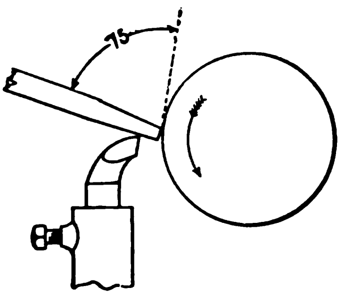


Fig. 85.

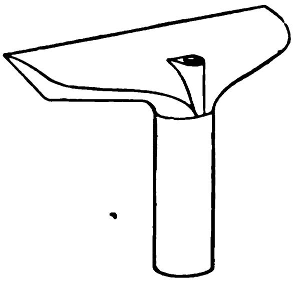


Fig. 86.

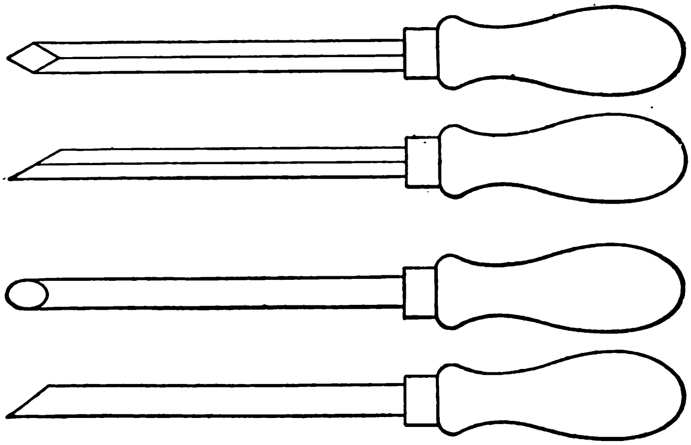


Fig. 87.

89. The graver can be used on brass for a great variety of operations; but its use, except in the hands of an expert workman, is attended with danger of catching in the soft metal and thus breaking the tool or spoiling the work.

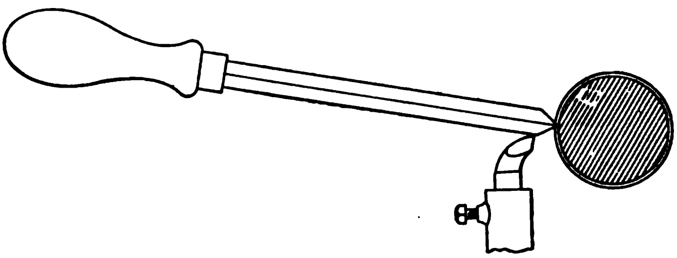


Fig. 88.

To make the hand lathe more rapid and certain in operation, it is frequently provided with a tool holder, called the slide rest, Fig. 90. This holds the tool rigidly and guides it mechanically, so that the work is done more rapidly than with hand tools. Slide rest tools are miniatures of those used on larger lathes, hence a description will not be given at this point.

Engine Lathe. When the slide rest is permanently attached to, and movable along, the bed of the lathe, and motion is automatically imparted to the tool, we have what is termed the engine lathe. This is one of the most common, as well as one of the most important machine tools, and one which can be made to serve for a wide variety of operations. For these reasons, it is entitled to a more extended description than that accorded to less typical forms.

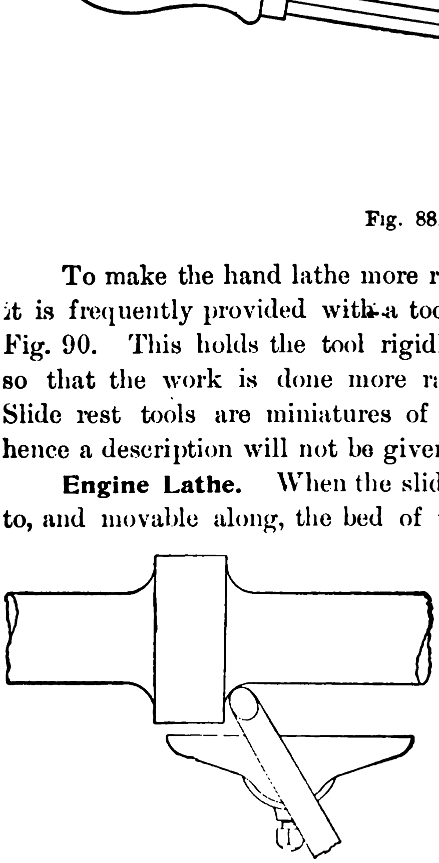


Fig. 89.

An ordinary form of screw cutting engine lathe is shown in Fig. 91, which is a representation of one of usual dimensions. It has a strong cast-iron bed A, carried on four well braced legs, that

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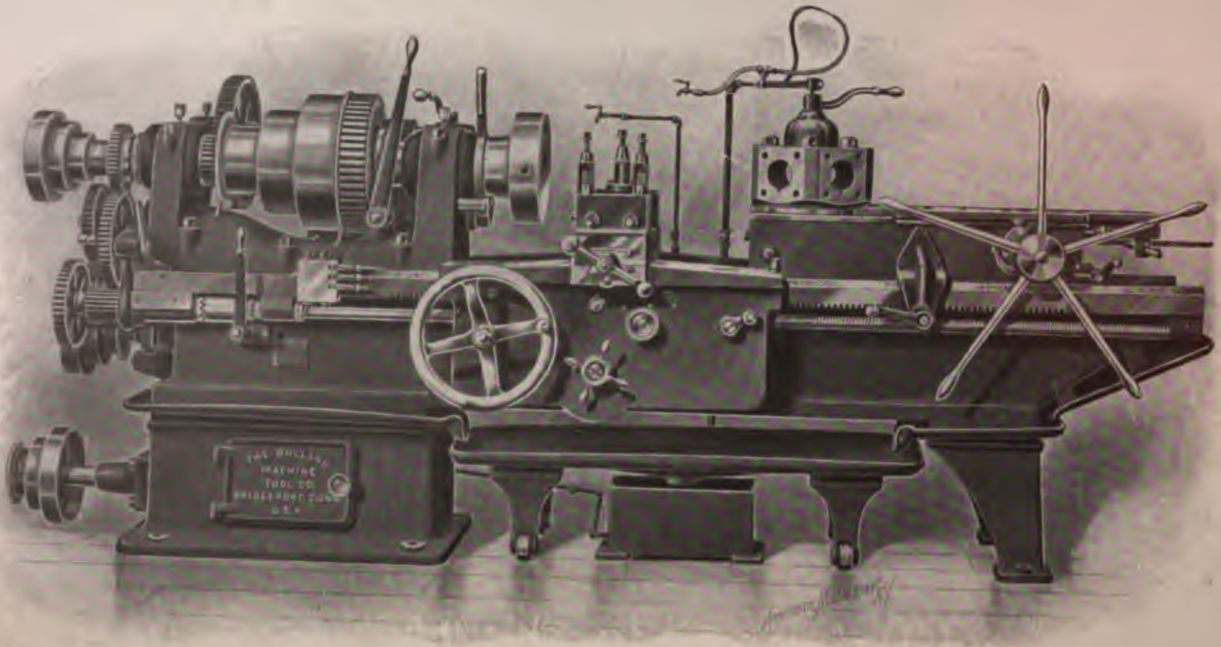
THE BULLARD
MACHINE
TOOL CO.
BRIDGEPORT CONN.
U.S.A.

TURRET MACHINE.

Swing 26 inches. Bed 10 Feet.

The Bullard Machine Tool Co.

may be bolted to the floor, though the weight of the machine may be sufficient to hold it in position. On the left-hand end of the bed there is fastened the head stock B, which carries the main running gear of the machine. At each end of the head stock there is a bearing for the spindle. Running loosely on the spindle and between the bearing is the cone pulley C to which the pinion D is attached.

The back gear is designed to reduce the speed of the spindle without changing the belt speed. The mechanism of the back gear is more clearly shown in Fig. 92. The large gear E alone shows in Fig. 91. It is driven by the pinion D which is attached to the cone. The pinion on the same sleeve as the gear E drives the gear at the right of the cone. This gear is keyed to the spindle. When the back gear is not in use it is thrown out of mesh with the gears on the pulley and spindle, by means of the shaft having eccentric bearings upon which it turns; at the same time the cone pulley is fastened to the gear at its right. The spindle then turns with the cone pulley. When the back gear is in use the spindle runs more slowly, with the belt on the same step of the cone, than it does when driven direct.

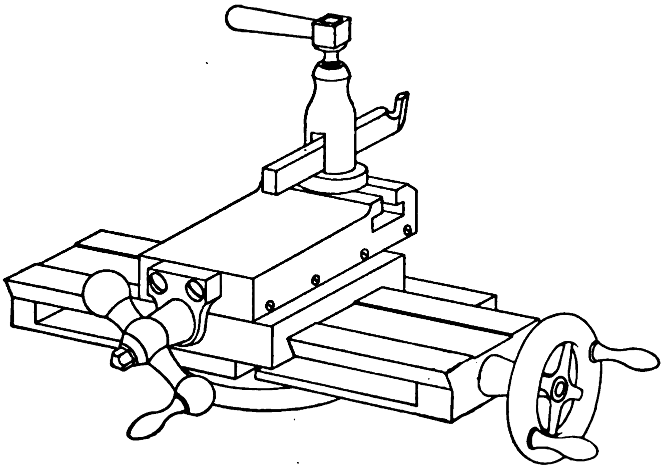
Fig. 90.

The spindle projects through the bearings at each end. At the right it is usually threaded to receive a face plate F. It is

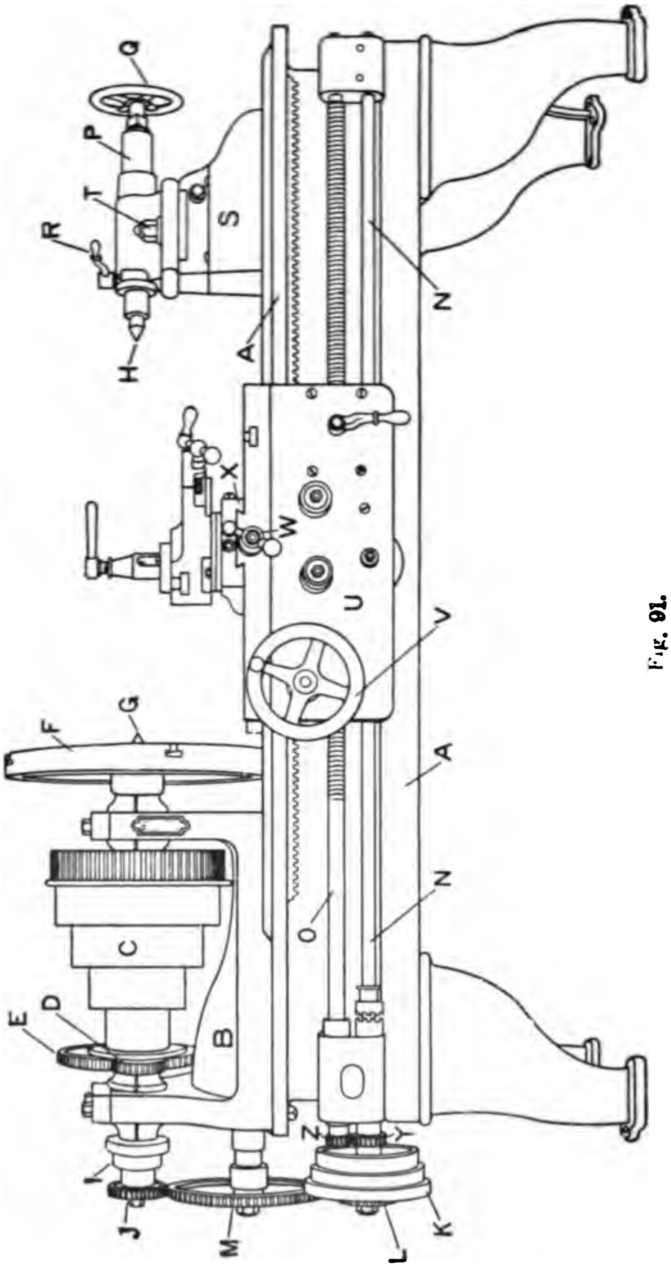

Fig. 91.

also bored out and tapered at the end for a center G. This center is called the *live center* because it turns with the spindle. The *dead center* H is in the tailstock, and hence does not turn. At the left the spindle projects beyond the bearings, and carries a small cone pulley I and a pinion J. The cone pulley serves as the driving pulley for a narrow belt running to the corresponding pulley K on the feed rod N. The pinion serves to drive, through the intermediate gear M, the lead-screw O.

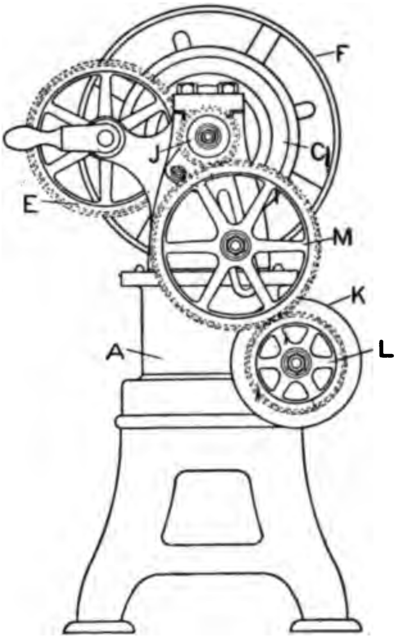

Fig. 92.

The work is held on the centers G and H, the distance between which is adjusted by moving the tailstock S (sometimes called the tailblock). The latter is held to the bed by a clamp and bolts tightened by the nuts T. To move the tailstock, these nuts are slackened and the stock moved to the proper position. The final adjustment is made by turning the hand wheel Q, which rotates a screw in the case P, which works in a nut in the spindle of the dead center H which is thus moved in and out. When the centers have been properly adjusted and the work is in position, the dead center is clamped by the handle R.

When work is to be turned, the tool is properly adjusted, and the carriage U moved along the bed. This movement is accomplished by means of gearing, which is placed behind the apron of the carriage, and driven by the shaft upon which the cone pulley K is keyed. The driving gear meshes with a rack beneath the upper ledge of the bed. Connection between the gearing and the shaft is made by a friction clutch. The carriage may also be moved by hand, by turning the hand wheel V, to which there is keyed a pinion directly meshing in the rack.

The tool is fed to the work and withdrawn from it by turning the cross feed handle W. This drives, by means of the screw and nut, the cross slide X. This arrangement permits any desired transverse or longitudinal position of the tool. The motion of the carriage is usually from right to left when at work. When screws are to be cut, a different feed is used. In ordinary turning there will be a variation in the relations between the rotation of the work and the longitudinal motion of the tool due to the slipping of the belt connecting the cone pulleys I and K, or to the slipping of the friction clutch connecting the shaft K to the driving gear.

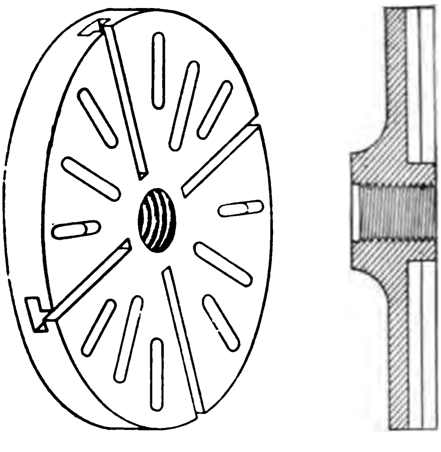
Fig. 93.

To cut a screw thread it is necessary that there shall be no relative change in the rotation of the work and the longitudinal motion of the tool. In other words, the tool must travel a given distance for every revolution of the work. To accomplish this, the carriage is driven by the lead-screw O working in a nut set in the carriage. The screw is, in turn, driven by the train of gears J, M, and L. The gear J is keyed to the spindle. The intermediate gear M runs loose on a stud. The gear L is keyed to the feed rod N, which transmits its motion to the lead-screw O by gears Y and Z. By changing the sizes of the gears used on the spindle and the screw, any desired thread may be cut. The size of the intermediate gear M has no effect on the thread being cut. It is used to connect the other two gears, and can be adjusted to any desired position for that purpose.

In this country the SIZE OF A LATHE is designated by the largest *diameter* it will swing over the guides, and by the length of the bed. The lathe illustrated is known as 24″ × 8′. In England the distance from the guides to the center is the unit of size, and, in a few cases, the greatest distance between centers is considered to be the length of the lathe. Thus a 15-inch lathe in England would be a 30-inch lathe in the United States.

The attachments usually furnished without extra charge are a large face plate of the full swing of the lathe, a steady rest, and a follower rest.

The small face plate is used only for driving the work indirectly through suitable attachments. The large face plate shown in Figs. 91 and 93 is used as a direct support for the work, the T-slots and other openings furnishing opportunities for bolting and clamping the work firmly to the face plate.

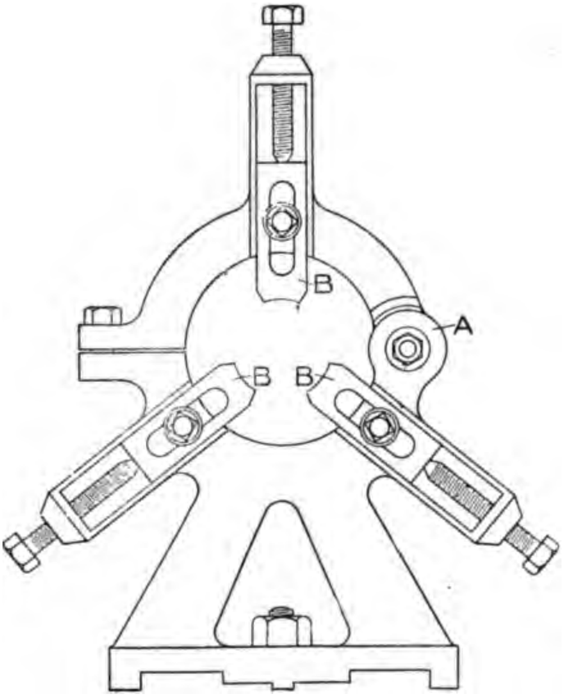

Fig. 94.

The Steady Rest. When work is being done on the end of a shaft so that the tailstock cannot be used, it is necessary to support the shaft in some other way. It is done by means of the steady rest shown in Fig. 94. This rest consists of a frame hinged at A, and fitted with three movable jaws, B B B. The rest is clamped to the lathe bed in the proper place. The jaws B B B are then adjusted to form a bearing for the work, care being taken that the axis of the work is parallel to the ways, or shears. Unless it is parallel, the work will not be turned true; that is, the end will not be square, but will be hollowed or conical, as shown somewhat exaggerated in the accompanying diagram (Fig. 95). The steady rest is also used to support long shafts that are being turned; it prevents such work from sagging at the center and thus being turned out of true.

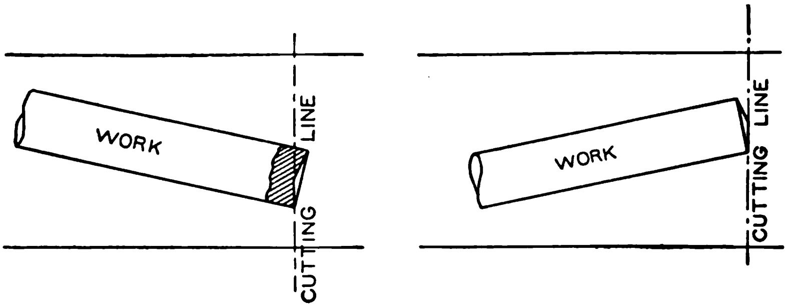

Fig. 95.

After adjusting the steady rest to size, it can be moved along the bed of the lathe without changing the relation to the lathe axis; but care must be taken not to reverse the steady rest in the lathe, as, in most cases, such action would necessitate a readjustment.

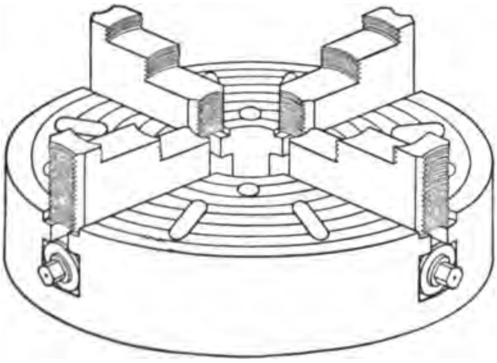

Fig. 97.

The names, back rest and center rest, are synonymous with steady rest, the use of the device often determining the name.

The follower rest serves some of the purposes of the steady rest, but is fastened to the carriage, and moves with it at the point of greatest stress. It may consist of adjustable jaws or a solid ring to slip over the piece being turned. It is especially valuable in turning shafting and other work where the ratio of length to diameter is very great. The follower rest is not very often used in shop practice, except on classes of work just mentioned. The extra attachments desirable for a lathe will now be briefly described.

Chucks. First in importance is the lathe chuck, Fig. 96. It consists of a body which is fastened to a special face plate in such a way that it is concentric with the spindle. The three jaws AAA can be moved in and out toward the center by turning the screw-heads BBB. These chucks are universal or independent. In the universal chuck all of the jaws are operated simultaneously. That is, when one of the screw heads B is turned, all of the jaws are moved an equal distance towards or away from the center. This makes it possible to put the work in position quickly if it is approximately round in its unfinished condition. With the in-

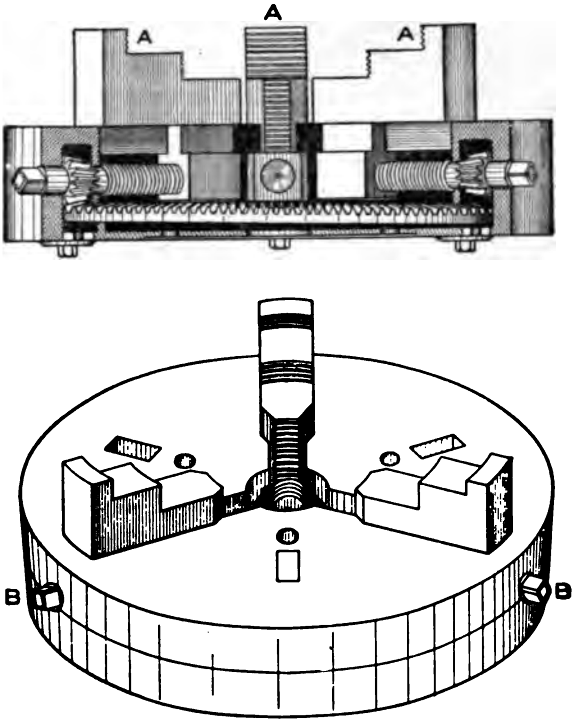

Fig. 96.

dependent chuck, Fig. 97, each jaw is operated separately. Such a chuck is used for holding pieces of irregular shape and those which must be held eccentrically. Frequently the universal and independent chucks are combined in one. Means are then provided for working the jaws separately or together as desired.

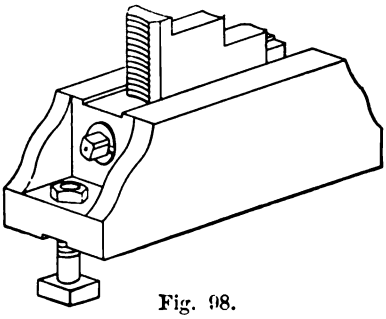
Fig. 98.

In using the universal chuck each screw should be tightened. The method of procedure is to place the work in the chuck, and turn one screw head until all of the jaws are in contact with the piece to be operated upon. Then turn the chuck and tighten each screw head successively until each one is tight enough. Owing to wear and lost motion, it is sometimes necessary to apply the wrench to each one three or four times before the final adjustment is reached.

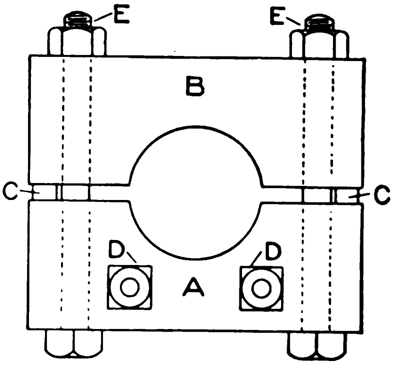

Fig. 99.

Lathe chucks are usually made with three or four jaws. Universal chucks generally have three jaws, while independent chucks have four. It follows that a combination chuck is not wholly satisfactory, because with three independent jaws it is very difficult to adjust work accurately, and with four universal jaws it is equally difficult to get every jaw to bear on the work. For certain classes of work, especially valves and pipe fittings, chucks with two jaws are often used

The large face plate of a lathe can be made into an independent chuck by attaching what are known as face-plate jaws; Fig. 98. In this case, there may be six, eight, or more jaws.

As these chucks are expensive it sometimes happens that a piece is to be held for which no provision is made. A chuck can then be made of wood. Such a chuck is shown in Fig. 99. Two pieces of wood, A and B, are bolted together by the bolts EE, while separated by the filling pieces CC. The piece is firmly bolted to a face plate by the bolts DD. The lathe is then run at high speed, and the interior bored out exactly the size of the piece that is to be held. The nuts of the bolts EE are slackened and the filling pieces CC removed. The work is then inserted, and by tightening the nuts EE, it is securely clamped between the pieces A and B.

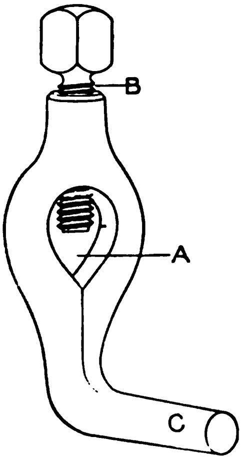

Fig. 100.

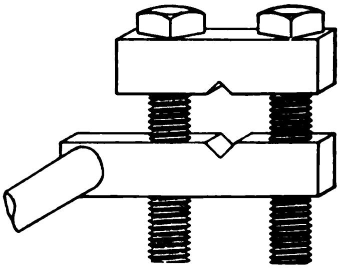

Fig. 101.

Lathe Dogs. As the frictional contact of the work on the live center is not sufficient to turn it, some device must be used to make the work turn with the center. To accomplish this a lathe dog is used. For round work, such as shafting, a dog like that shown in Fig. 100 is often used. The shaft or piece to be turned is placed in the hole A, and held firmly in place by the set screw B. The tail-piece C is put through a hole in the face plate and the work rotates with the live center.

While this type of dog is satisfactory in most cases, the fact that the contact between the dog and the face plate is beyond the end of the piece, introduces a bending strain which is appreciable in slender work. To avoid this, dogs are made with a straight tail, and driven by a stud projecting from the face plate.

For work other than round, a dog such as that shown in Fig. 101 may be used. The work is placed between the jaws, and held in position by the bolts. The holes in the upper jaw are made larger than the screws in order that the angle between the jaws may be varied. The connection between the face plate and dog is made as with Fig. 100.

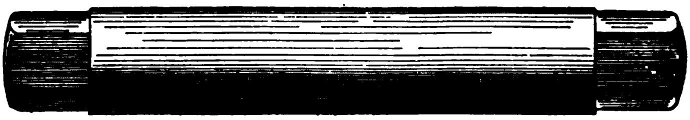

Fig. 102.

Mandrels. Another method of holding work is by the use of a mandrel. This is a piece of steel with a slight taper; the ends are flattened for the lathe dog, as shown in Fig. 102. It frequently happens that a piece with a hole in it is to be turned or finished over its outer surface. In this case a dog cannot be used, and it is troublesome to hold it to a chuck. Such a piece is shown in Fig. 103. This is a stuffing-box gland. If it were to be held by the jaws of a chuck the face A could not be reached at all, and only a portion of the edge B, whereas a dog clamped to it would offer even greater obstruction. The method of using the mandrel is to ream the gland out, so that it can be driven upon

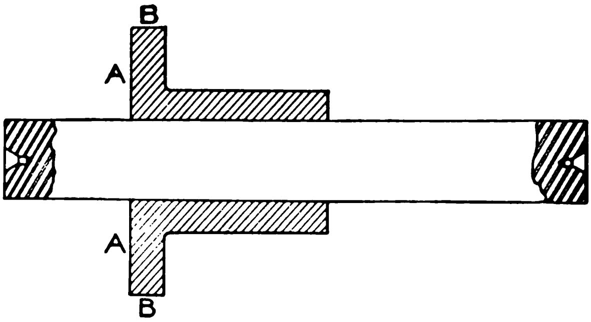

Fig. 103.

the mandrel. When this has been done the frictional resistance between the two will be sufficient to drive the piece. In this manner it can be finished over its whole surface with but one setting in the lathe. All finishing possible may be done while it is in the chuck, leaving, in this case, only the face A and edge B to be finished while on the mandrel.

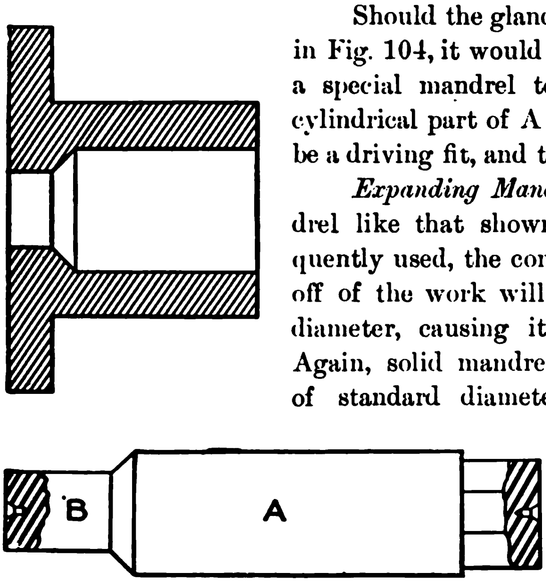

Fig. 104.

Should the gland be shaped, as shown in Fig. 104, it would be necessary to make a special mandrel to fit the bore. The cylindrical part of A of the mandrel must be a driving fit, and the part B a loose fit.

Expanding Mandrels. Where a mandrel like that shown in Fig. 102 is frequently used, the constant driving on and off of the work will wear it to a smaller diameter, causing it to become useless. Again, solid mandrels are usually made of standard diameters, varying by sixteenths of an inch. It sometimes happens that a piece to be turned has a hole which will not fit any standard solid mandrel.

To overcome these difficulties an expanding mandrel, shown in Fig. 105, is used. This is really a chuck so arranged that the grips can be forced out against the interior of the hole. When the work has been finished the grips are again drawn in and the piece removed. Another form of expanding mandrel is shown in Fig. 106.

Centering. A piece to be turned is supported on the two centers of the lathe. In order that this may be done, the ends are prepared by drilling a hole in each and countersinking it. This is called centering the work. The countersink should be of exactly the same angle as the lathe center upon which it is to run. The hole should be drilled deep enough so that the point of the lathe center may not strike. The shape of the hole is shown in Fig. 107. The angle of the hole varies from 40° to 90°, but 60° is the generally accepted standard. The effect of using a 60° hole on a 90° center is shown in Fig. 108. The result of such an application is that the bearing will be concentrated on a

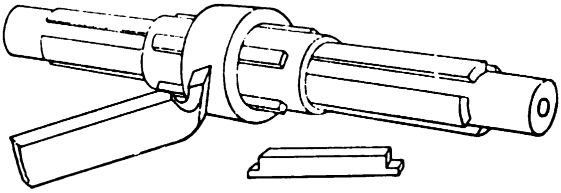

Fig. 105.

line AB causing rapid wear of the outer end of the hole, and a cutting of the dead center.

The size of center holes varies with the weight of the work and the character of the operation. Heavy work and rough turning require large center holes, while small work and fine turning can be done without countersinking deeply. As bearing surfaces in cast iron must be large to be satisfactory, center holes in cast iron are likely to give trouble by unequal and rapid wear. When turned work in cast iron must be very accurate, it is well

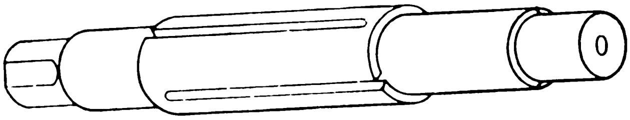

Fig. 106.

to drill a large hole in each end, drive in a plug of wrought iron or mild steel, and form the center holes in the plugs thus driven.

When the piece has been put in place, the dead center should be oiled and screwed up into position. It should be tightened so that there is no lost motion and yet allow the work to turn freely.

The turning of shafts and bars is not, however, the only kind of work to be done on a lathe. Pieces are to be turned that are thin, that have holes through the center, and which are so shaped that they cannot be held upon the centers. In such cases it becomes necessary to hold the work firmly without distortion, as may be done by use of the lathe chuck.

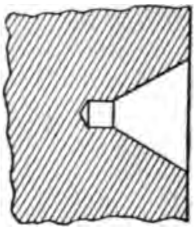

Fig. 107.

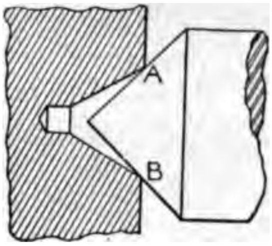

Fig. 108.

Still another method of holding work is that shown in Fig. 109. The piece is clamped to the face plate. When this is done there should be a bearing on the face plate immediately beneath the clamping strap. For example consider Fig. 110. Suppose a disk having four feet on one side is to be faced off on the front.

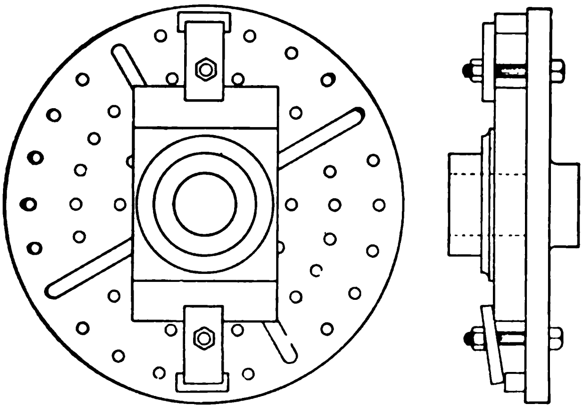

Fig. 109.

The clamps should be placed directly over the feet as in B. If they are placed between the feet at EE the work will be sprung out of shape as shown by the dotted lines in A. Then, when the tool has done its work the shape of the piece, while bolted to the face plate, will be as shown in C. As soon as the pressure of the straps is removed the elasticity of the metal will cause the piece to assume the convex form shown in D, whereas, if the straps had been placed as shown in B, no distortion would have been produced.

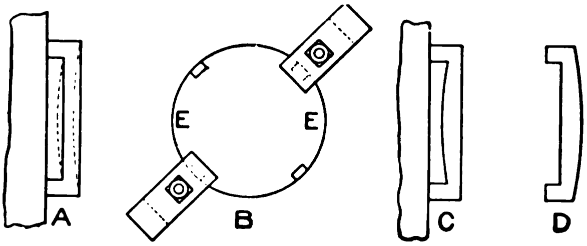

Fig. 110.

An angle iron may be clamped on a face plate, as shown in Fig. 111, presenting a surface parallel to the lathe axis to which work may be attached. The angle irons may of course be at any angle to the face plate, but 90° is the one most commonly used.

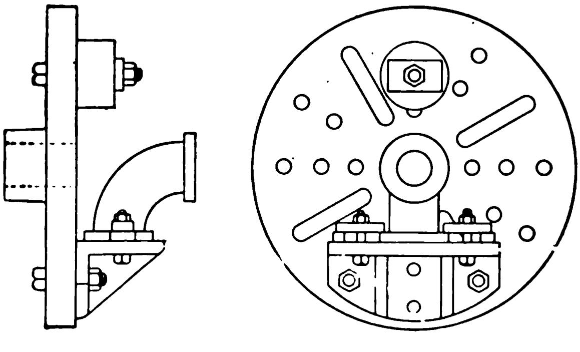

Fig. 111.

When work is held in this manner, it is desirable to counterbalance it, as is also shown in Fig. 111.

Adjusting Pieces to Center. Whenever a piece is to be turned in a lathe it is necessary to adjust it so that its rough outline is approximately concentric with the lathe centers. This is done by bolting it lightly to the face plate and running the lathe. While running, a piece of chalk is held so that the projecting portions will strike it. This marks the piece, and indicates the part that is *farthest* from the center. The lathe is then stopped and the piece shifted, *moving the chalk mark towards the lathe center.* This is repeated until the chalk makes a continuous mark around the whole circumference. The piece may then be considered to be centered.

Suppose it is necessary to center a piece having a hole that must run true. In this case the inside of the hole must be used as a guide. Let Fig. 112 represent the hole with the thin shell, and A a chalk mark made as described for centering by the outside. In this work the *chalk mark must be moved away from the center.* A lathe tool may be used as shown in Fig. 113 to center a piece that is to be bored.

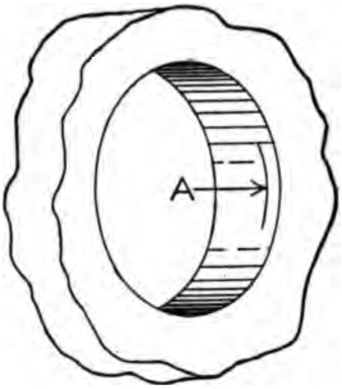

Fig. 112.

Where a piece has already been turned, greater accuracy is demanded, and a surface gage may be used to advantage. Set the gage on the bed or carriage of the lathe, and place one of the points in contact with the work. Rotate the work as before, and note where the point touches the surface. This point is to be treated in the same way as the chalk mark explained in a preceding paragraph.

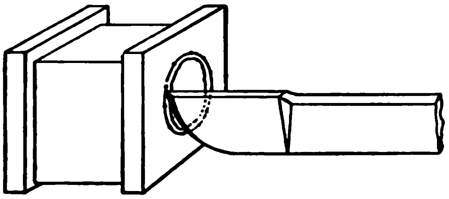

Fig. 113.

A still more accurate method of centering a piece of turned work on a face plate is to use some form of graduated indicator, such as the Starrett indicator, Fig. 114. This is held in the tool post, and the contact point brought against the work until the indicating arm is at zero. If the work is now slowly rotated by hand, the indicator will show just where the work is out of true, and being graduated in thousandths of an inch, will also show how much. By careful adjustment, the piece may be centered to the degree of accuracy required.

Instead of locating a cylindrical surface concentric with the axis of the lathe, it often happens that a point is to be located in the axis. For this purpose, the center indicator, Fig. 115, is used. The free end of the short arm is placed in the point to be centered (usually a prick punch mark), the fulcrum being held in the tool post; when the work is rotated, the free end of the long arm not only shows the error, but magnifies it in proportion of the length of the short arm to the length of the long arm. By using a comparatively long arm, the point can be very closely centered.

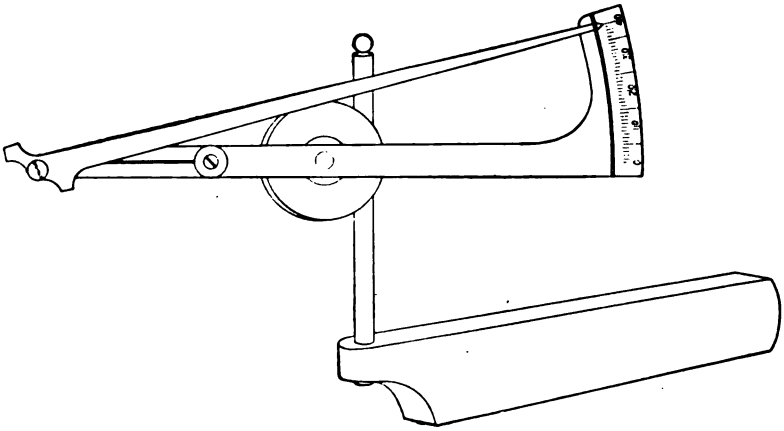

Fig. 114.

Centering Finished Work. After making the center punch mark in the end of the piece, it is drilled and countersunk. This must be done very accurately, but frequently the drilled hole or the countersink will not be in the exact center. See Fig. 116. This may be caused by uneven grinding of the drill, eccentric motion of the drill point (due to the inaccurate running of the spindle), or the distortion of the metal by the center punch. If the countersink is not exactly in the center, it must be drawn back to the center. This is generally done by the small round-

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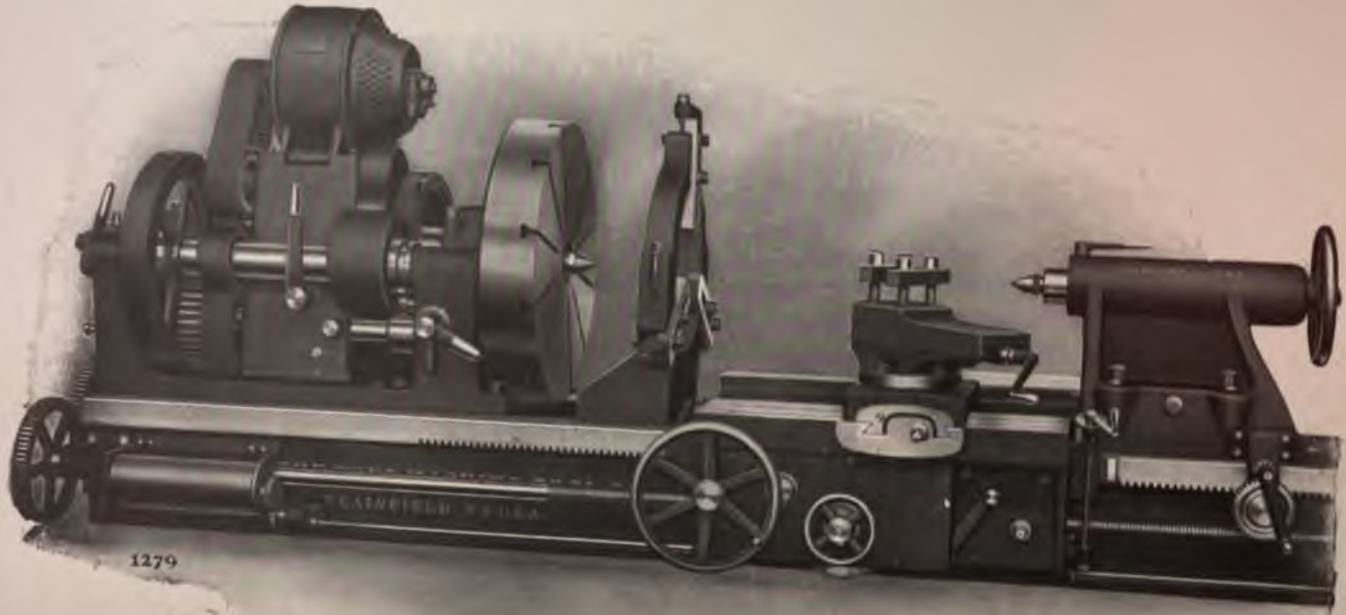
ASTOR, LENOX AND
TILDEN FOUNDATIONS



42-INCH POND LATHE.

Niles-Bement-Pond Company.

nosed chisel and a hammer. The method of doing this work is as follows: After making the center punch mark, the hole is drilled and then countersunk slightly. The work should now be stopped; and if the circumference of the conical hole is not concentric with the circumference of the piece a groove should be cut down the side farthest from the outer circumference, as shown in Fig. 117. The depth of the groove, which should be near the center, depends upon the amount of eccentricity. The countersink is again started and the groove drilled out. If the circle is not yet concentric, the process is repeated.

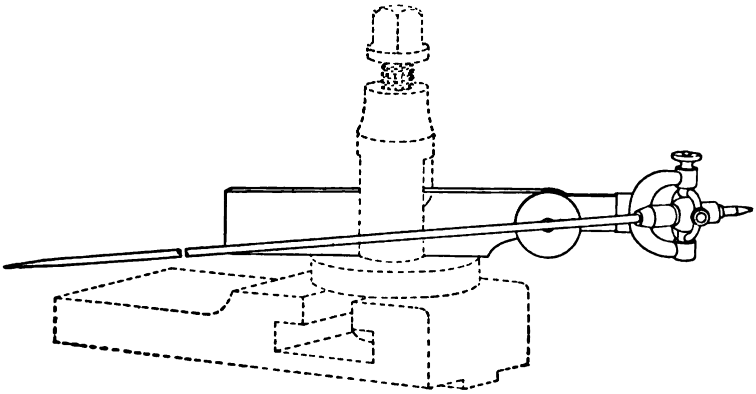


Fig. 115.

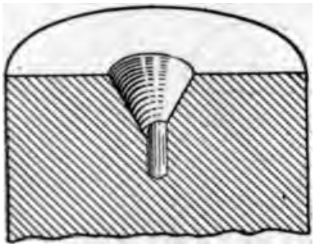


Fig. 116.

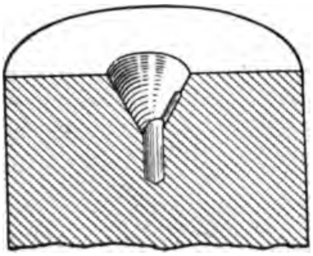


Fig. 117.

Lathe Tools. The cutting tools used in lathes are of a great variety of shapes. These shapes are adapted to the work that is to be done, and to the kind of finish that is to be left upon the metal. There are two fundamental requirements that all tools must fulfill: *The cutting edge alone must touch the metal; the edge must be keen.* A typical form of tool is shown in Fig. 118. The cutting edge of the tool at A is in contact with the work. The bottom line A B runs back from the metal and does not touch it. The top face A C slopes down and back. The line A D is a tangent at the cutting point, and the line A E is radial at the same point. Therefore, the angle D A E is always a right angle or 90°. The angle D A B is called the angle of *clearance*, and should be small; in lathe tools, not over 10°. The angle C A E is called the angle of *rake*, and should be as great as circumstances will permit; about 20° on lathe tools for wrought iron and steel, leaving 60° for the *solid* or *cutting* angle, which is the same angle as is used for a cold chisel.

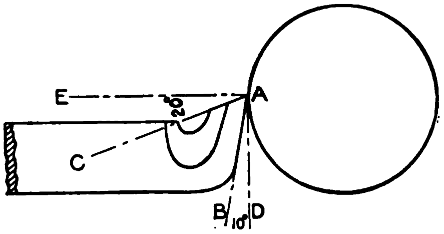


Fig. 118.

Clearance prevents the tool from rubbing on the work, while rake adds to the keenness of the cutting edge, and gives freedom to the removal of the chips. A tool should have sufficient strength at the point to do the work required.

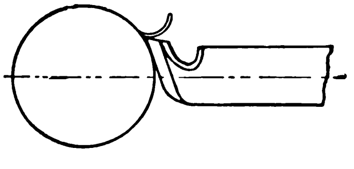


Fig. 119.

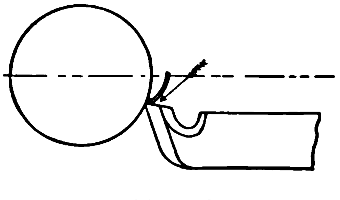


Fig. 120.

The tool should be set so that the cutting edge will be very nearly at a horizontal line, passing through the axis of the work. Many machinists set the cutting edge a little above the horizontal line. When so set the stress tends to force the tool down along the line of its greatest strength. The tool may, however, be set too high. If this is done, as in Fig. 119, the angle of clearance will disappear, and the curve of the work will rub against the bottom of the tool. This will tend to force it out; it will heat the steel and produce a rough surface on the metal being turned. If, on the other hand, the tool is set too low, as in Fig. 120, the cutting edge does not stand in line with the motion of the work at the point of contact. The result will be that the metal will be scraped rather than cut, as there is no rake, and the pressure upon the tool will be in the line of its lowest power of resistance, as indicated by the arrow. Such a position might cause the point of the tool to break off. It will also cause the tool to tremble or chatter as it removes the chips, leaving a rough and wavy surface on the metal.

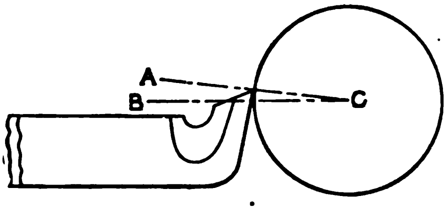


Fig. 121.

As stated above, many machinists prefer to set the cutting edge a little above the center; if this is done, the rotation of the work has a tendency to depress the point of the tool a little, bringing it, while cutting, nearly to the center. The amount the tool is set above the center is slight, and of course depends upon the character of the work. The angle A C B, Fig. 121, should be only about 5 or 6 degrees.

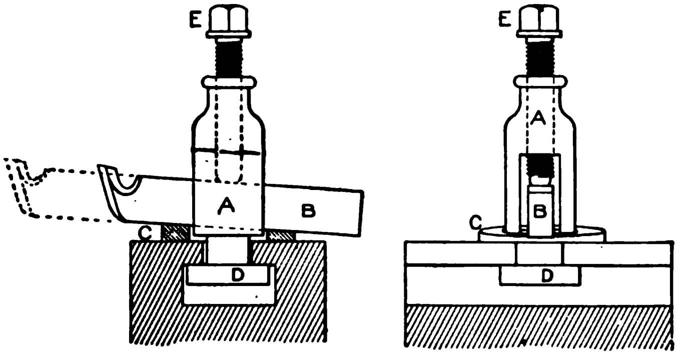


Fig. 122.

The tool is usually held to the carriage by means of a tool post, shown in Fig. 122. The post consists of a piece with a slotted hole through the center for the tool B. A ring C slips over it and rests upon the body of the carriage. This ring may be beveled as shown, to provide vertical adjustment for the point of the tool. The post has a collar D at its lower end that goes loosely into a slot in the carriage. At the top there is a set screw E. When the tool has been properly adjusted by turning the ring C to give it the correct elevation, the set screw is tightened down upon the top of the tool. This raises the tool post to a bearing on the under side of the slot, and clamps the whole carriage firmly in position.

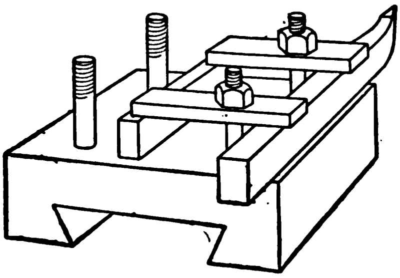


Fig. 123.

In setting the tool, it should be done with the cutting edge as far back towards the supporting ring as possible. If it has too much overhang, as shown by the dotted lines of Fig. 122, it will spring under the pressure of the work and chatter.

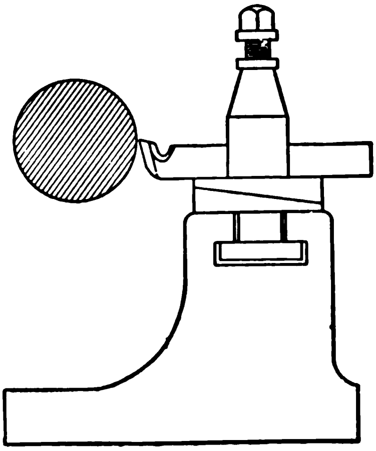


Fig. 124.

While this form of tool post is used more than any other, there are certain objections to it. In the first place, changing the height of the tool point also changes the angles of rake and clearance. These are supposed to be correct when the base of the tool is horizontal. Any change from this position will alter these angles materially. Again, this post is not rigid enough for heavy work. On lathes of over thirty inches swing the style of tool-holder shown in Fig. 123 is often employed.

English manufacturers use it almost exclusively on all sizes. There is no provision for raising and lowering the point of the tool; and while this is not of serious importance on large lathes, 30-inch and over, it becomes a matter of moment when turning such work as is usually handled in lathes of 14-inch and 16-inch swing.

The form shown in Fig. 124 has two beveled rings to adjust the height of the tool.

The Lipe tool post, shown in Fig. 125, combines the good points of all the other forms; the tool can be held by one or two screws as the character of the work may require, and the tool may be adjusted vertically and horizontally after being clamped down. The construction and operation of this tool post are so evident from the illustration, that further description will not be given.

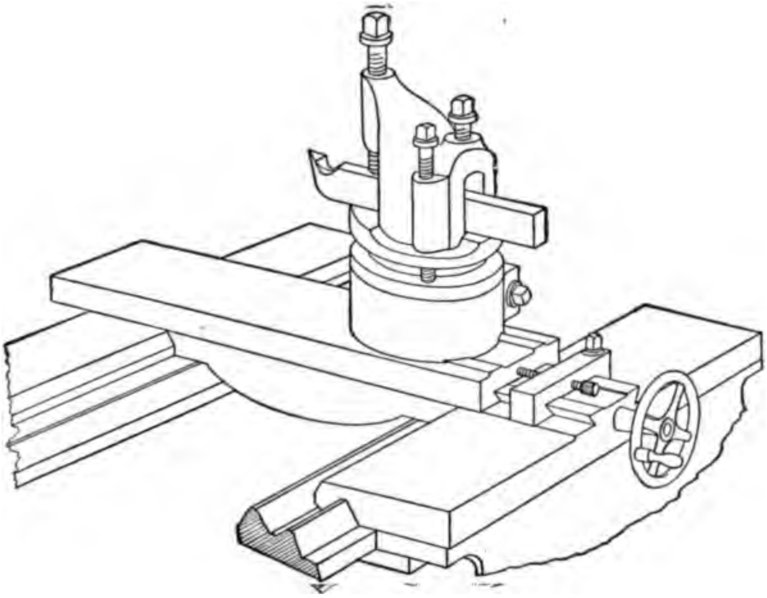


Fig. 125.

An entirely different method of adjusting the tool point is by means of what is called the elevating or rise-and-fall rest shown in Fig. 126. In this type there is a T-shaped casting carried on the upper part of the carriage, supported by trunnion screws at the front, and by an adjusting screw at the rear. With this is used a tool post as shown in Fig. 122 with a plain ring. The elevating rest is used quite extensively on small lathes, but the convenience of adjustment is gained by a loss in rigidity. The cross rail is light, and the elevating portion, being supported at three widely separated points, lacks stiffness. As the effective swing over the carriage is limited by the height of the cross rail and the parts carried above it, they are made light — too light in many cases.

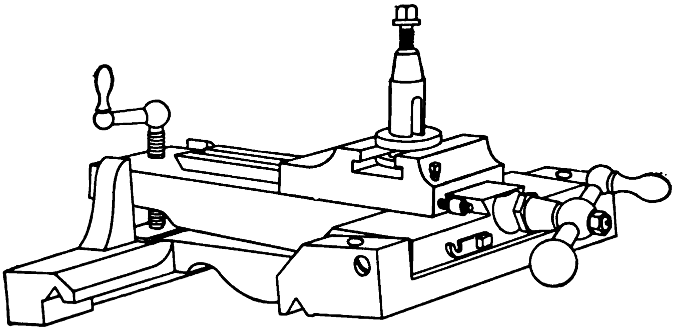


Fig. 126.

Turning Tools. The side or facing tool, Fig. 127, is the most common form of lathe tool. It is used for squaring up the ends of shafts, facing shoulders, and similar work. While the ordinary forms will not remove a large amount of metal, they can, when made thick and heavy, be used for roughing cuts on the surface of cylindrical work. The common form is made slender in order to work between the dead center and the work in squaring up ends.

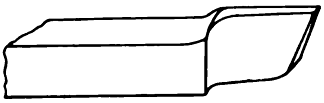


Fig. 127.

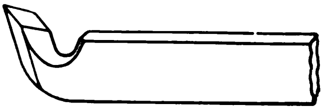


Fig. 128.

A common form of tool for turning wrought iron and steel is the diamond point shown in Fig. 128. The name is derived from the shape of the top face. This tool has both front and side rake which allows a keen edge without reducing the strength. It is used for finishing only when the point is ground slightly rounding and a fine feed is used. In finishing, but little metal should be removed. The *Feed* of a tool is the amount of longitudinal advance at each revolution of the work. For roughing out cast iron, a strong and rapid working tool is a round nose with considerable side rake. For finishing wrought iron and steel, a modification of the diamond point, as shown in Fig. 129, is often used. For cast iron, a square-nosed tool, Fig. 130, should be used. It must be carefully ground and accurately set, otherwise it is very likely to gouge into the softer parts of the metal. When finishing wrought iron and steel, the tool should be liberally supplied with oil or soda water. Cast iron must always be worked dry, both in roughing and finishing.

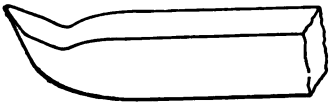


Fig. 129.

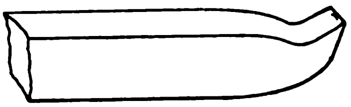


Fig. 130.

The cutting-off or parting tool is illustrated in Fig. 131. The blade is quite narrow; as narrow, in fact, as the character of the work will allow. This is necessary in order that the stock may not be wasted. As the blade must be narrower at the shank and at the bottom than it is at the cutting edge, it follows that the tool is weak. It must be set horizontally so that, as the tool is fed to the work, the cutting edge only will touch the metal. It must also be set so that the cutting edge will pass through the axis of the work as it is fed to the center. If set too high, it will cease to cut before the center of the work is reached, while if too low, the tool has a poor scraping action, and will leave a portion of the work uncut. On work held between centers, one should not

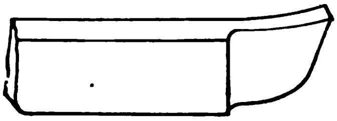


Fig. 131.

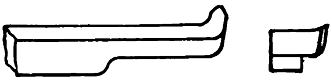


Fig. 132.

attempt to cut to the center of the piece, as the work will surely ride up onto the tool.

Boring Tools. When a hole is to be bored in a lathe, tools of a different shape from those used in turning must be used. The general form of the tool is shown in Fig. 132. The length of the shank at A depends on the depth of the hole to be bored, for it must be long enough to reach from the tool post to the bottom of the hole. This overhang makes the tool more likely to spring, and necessitates a much lighter cut than can be taken when removing the same amount of metal by outside turning tools. The result of this lighter cut is seen in the increase of time required to remove a given amount of stock. The shape of the cutting edge is practically the same as that of the tools for turning, except that the boring tool must have more clearance to avoid striking the work. Therefore, with the same solid angle, the tool will have less rake. The reason for this will be seen by comparing Figs. 118 and 133. In Fig. 118 it will be seen that the surface of the work is outside a tangent at the cutting point, and can never interfere with the bottom of the tool. In Fig. 133 the work surface is inside the tangent; and, unless the tool has a large amount of clearance, it will cause trouble by striking the concave surface.

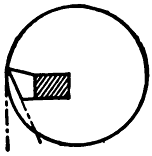


Fig. 133.

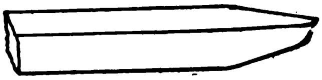
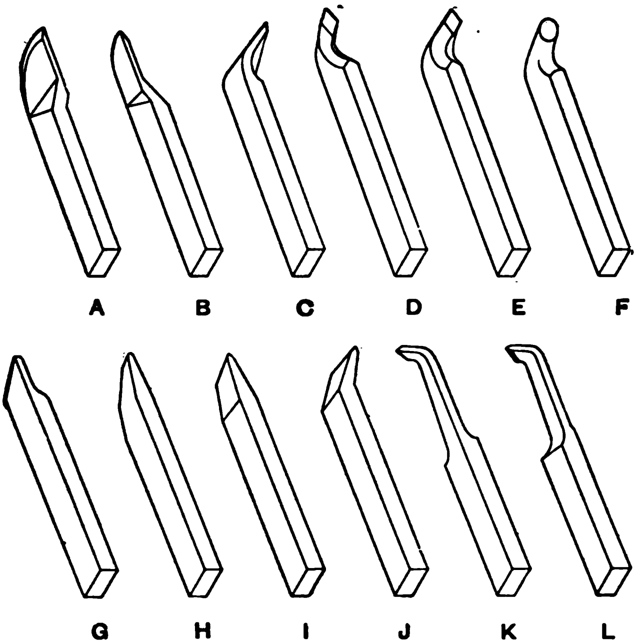


Fig. 134.

Tools for brass differ from those used on steel and iron in that they have no rake. A tool suited for brass is shown in Fig. 134. Brass is a very brittle metal, and the chips break off as soon as started from the main body. When turning wrought iron and steel, on the other hand, the metal does not break, but forms long spiral chips if the tool is in good condition. If a tool with rake is used in turning brass, the work will not only be rough in appearance, but there is great danger of the tool gouging into the stock and spoiling the work or tool, possibly both. The finishing tools for brass may be square or round nosed, without rake; in fact, a small amount of negative rake will produce a much better surface. When the brass contains a large percentage of copper, some rake may be required owing to the ductility and toughness of the metal.

Fig. 135 shows common forms of lathe tools.

The shape of the tool has a very important influence on the amount of work it can be made to do. As has already been explained, these shapes vary with the different metals that are being worked, and also with the class of work performed. It is highly important that the cutting angles be correctly formed. While hand grinding on the emery wheel and grindstone is fairly satisfactory, the best results can only be attained by the use of a regular tool-grinding machine, shown in Fig. 136. In addition,



A Left-hand Side.
B Right-hand Side.
C Right-hand Bent.
D Right-hand Diamond Point.
E Left-hand Diamond Point.
F Round Nose.
G Cutting off.
H Roughing.
I Threading.
J Bent Threading.
K Boring.
L Inside Threading.

Fig. 135.

tools for fine finishing should be carefully whetted on a fine oil stone.

The cutting speed is an important matter. This varies with the shape of the tool, the quality of the metal being worked, and the strength of the lathe. The amount of metal removed in a given time is, therefore, equally variable. It is impossible to make a correct estimate of the time that a given piece of work will require unless all of the above elements are known. For approximate estimates, the speeds of cutting tools may be taken to range about as follows:

In cast iron,	from 30 to 40 feet per minute.
In wrought iron,	from 25 to 30 feet per minute.
In steel,	from 15 to 25 feet per minute.
In brass,	from 60 to 100 feet per minute.

Suppose a wrought shaft 6 feet long and 4 inches in diameter is to be turned. Let the lathe be capable of carrying a feed of $\frac{1}{32}$ inch per revolution. The shaft has a circumference of $4 \times 3.1416 = 12.5664$ inches. To give the tool a cutting speed of 25 feet per minute, the shaft must make $\frac{25 \times 12}{12.5664} = 24$ (about) revolutions, giving a feed of $\frac{1}{32} \times 24 = \frac{3}{4}$ inch in that interval of time. At $\frac{3}{4}$ inch per minute, it will take $(6 \times 12) \div \frac{3}{4} = 96$ minutes to take a cut the whole length of the shaft. The amount of feed is really the governing element. This may be as much as $\frac{3}{16}$ inch per revolution, and, for finishing cuts, may not be more than $\frac{1}{100}$ inch. The depth of the cut also influences the time required to finish a given piece. This may vary from $\frac{1}{100}$ to $\frac{1}{2}$ inch. All depends on the shape of the tool and the strength of the lathe.

The cutting speeds given above are what may be used with the best grades of tool steel, such as Jessop's, but by using air-hardening or tungsten steels, the speed of cutting may be very much increased over the values given above. These high-speed steels are rapidly coming into favor, more especially for heavy roughing cuts. Not only are the cutting speeds increased, but the chip is made heavier both in depth and feed up to the point where the lathe refuses to carry the load. The ability of this quality of steel to stand high temperatures without injury is the feature which enables it to do work at this rate.

For cooling the tool while performing heavy duty, a solution of sal soda is preferable to water, as it prevents rusting of the work and machinery. The lubricant does not assist in the severing of the metal; even with a most liberal supply, it is doubtful if any ever reaches the point of the tool. Its office is simply to keep the tool cool. If a tool becomes overheated, the edge begins to turn over and it becomes dull.

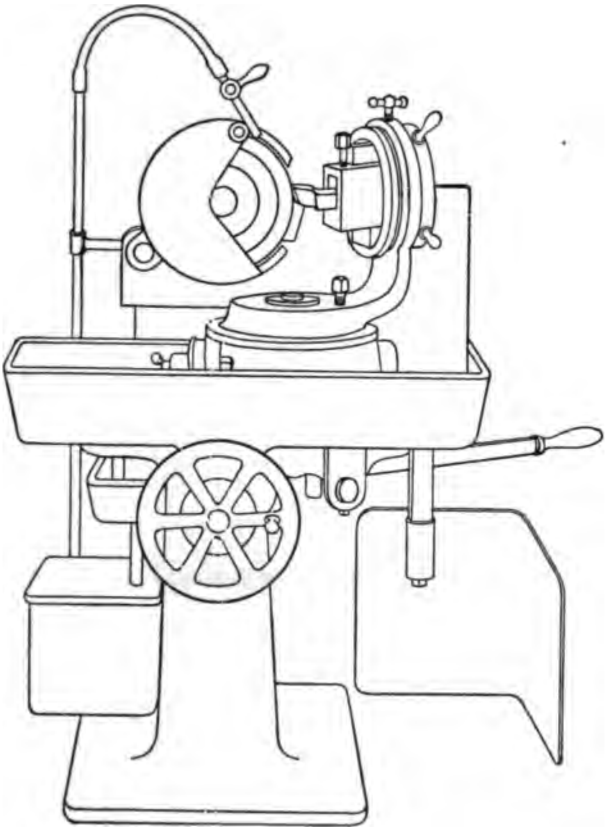


Fig. 136.

Referring to Fig. 120, it will be seen that the chip, as it is being removed, presses down on the top face of the tool. This pressure increases with the depth of cut and the feed. The friction would soon cause a high temperature in the tool if it were not relieved by the lubricant. The lubricant cools the tool by absorbing a portion of the heat, and lessens the amount of heat developed by reducing the friction between the tool and the chip. Clean, pure water is the only lubricant which can be used on cast iron, but the rapid rusting which follows its use makes it undesirable. Brass is also usually turned dry. Prime quality lard oil is sometimes used for cooling the tool; but the greater cost prevents its extended use, unless some means are provided to collect, separate, and filter it.

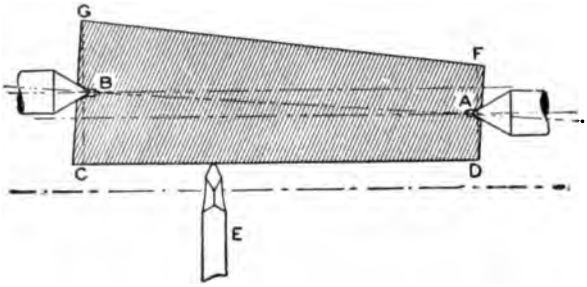


Fig. 137.

Turning. The first operation usually performed on a piece of work when placed in the lathe is facing or squaring up the ends. This must be done to get a uniform bearing for the centers. The finishing of all surfaces at or nearly at right angles to the axis of the work is classed as facing, and the side tool (Fig. 127) is usually employed. For roughing cuts the cutting face of the tool is placed at a slight angle to the work surface in order to remove the metal quickly; but for finishing cuts it is placed nearly flat against the work, so that a light thin chip may be taken.

Turning the cylindrical portions of the work is next done by the use of the diamond point or similar tool. Roughing cuts are taken to within about $\frac{1}{64}$ inch of the finished size, and a fine finishing cut reduces the work to the exact diameter. For roughing cuts, common calipers should be employed, while for finishing cuts, the micrometer caliper is most suitable. All measurements must be taken with the lathe at rest, as motion of the work renders close calipering impossible.

Turning a Taper. It frequently happens that a piece must be turned tapering; that is, one end is to have a greater diameter than the other. There are three ways of accomplishing this result: setting the dead center over, the use of the compound rest, and the use of the taper attachment. Setting the dead center over is the most common method. Provision is generally made for moving the dead center laterally towards the front or rear of the bed according to the taper required. With the dead center set over, the tool will be at unequal distances from the live and dead centers, because its movement is parallel to the axis of the lathe. This is shown in Fig. 137. The piece to be turned is placed upon the centers A and B, and the dead center is moved from the axis a distance equal to the difference between the radii A D and B C. This leaves the side D C parallel to the center line of the lathe; hence the tool will be fed along this line. The objection to doing work by this method is that the lathe centers do not have full bearings at the ends of the work, and the center holes are likely to wear out of their true positions.

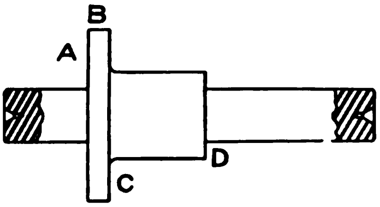


Fig. 138.

If the taper is to be turned on a piece held by a mandrel, or if the taper is to extend but a part of the total length of the work, the amount of set-over for the dead center must be calculated in the same manner as though the taper were to extend the whole length of the mandrel or work. In other words, the amount of set-over for the dead center is determined by the distance between the centers and the rate of taper.

For example: Suppose the mandrel in Fig. 138 to be 16 inches long, and the piece of work C D which is to be turned tapering, is 4 inches long; suppose also, that the diameter at D is to be $\frac{1}{4}$ inch smaller than at C. Then for one inch of length, the difference in diameters would be one-fourth of $\frac{1}{4}$ inch, or $\frac{1}{16}$ inch, and for a length of 16 inches it would be sixteen times $\frac{1}{16}$ inch, or 1 inch. Since the set-over is equal to the difference of the radii, the set-over for the 16 inches would be one-half of 1 inch, or $\frac{1}{2}$ inch.

This, then, would be the set-over for the work under consideration, and for any piece to be tapered at the rate of ¼ inch in 4 inches when held on a 16-inch mandrel.

EXAMPLES FOR PRACTICE.

1. A tapered bushing 3 inches long and of 4 and 4½ inches outside diameters is driven on a 12-inch mandrel for turning. How much must the dead center be set out of line in order to do the work? Ans. 1 inch.

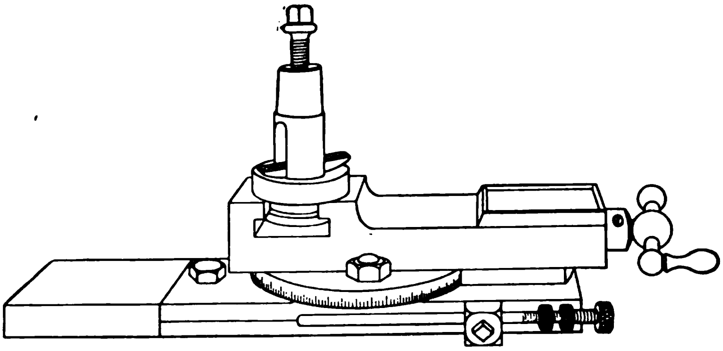


Fig. 139.

2. A connecting rod 6 feet long is to be turned tapering from the center to the neck back of the stub-ends. This distance is 26 inches. The diameter at the center is to be 3 inches, and at the neck 2½ inches. How much offset must be given to the dead center? Ans. .692+ inches.

3. A shaft had a taper 2 feet long turned on one end. The large end of the taper was 4 inches in diameter, and the small end was 3 inches in diameter. The dead center was set over 1 inch. How long was the shaft? Ans. 4 feet.

The machinist generally sets over the dead center as accurately as possible and takes a roughing cut. The taper is then tested by a careful comparison of the diameters or by trying it in a tapered hole of the proper angle, and the center set more accurately. Setting over the dead center does not give accurate results, on account of the fact that the centers do not have a true bearing at the ends of the work. The shorter the work, compared with the amount of set-over, the greater the inaccuracy.

In turning a taper with the compound rest, the work may be held in a chuck, on the faceplate, or between the centers. The compound rest, Fig. 139, is then set at such an angle that the direction of the motion of the tool will coincide with the required taper. Several methods are employed for this adjustment of the rest. The tool is then fed to the work by means of the feed handle attached to the compound rest.

The taper attachment, Fig. 140, is in the form of a guide which is bolted to the back of the lathe. It can be set at any desired angle with the axis of the lathe, the limit usually being a taper of about three inches per foot. The guide is graduated so that calculations based on the length of the work are unnecessary. A slide moving with the guide is attached to the cross-feed of the carriage. The cross-feed is loosened, and, while the carriage is moved by the feeding mechanism, the tool is moved in or out according to the direction of the taper.

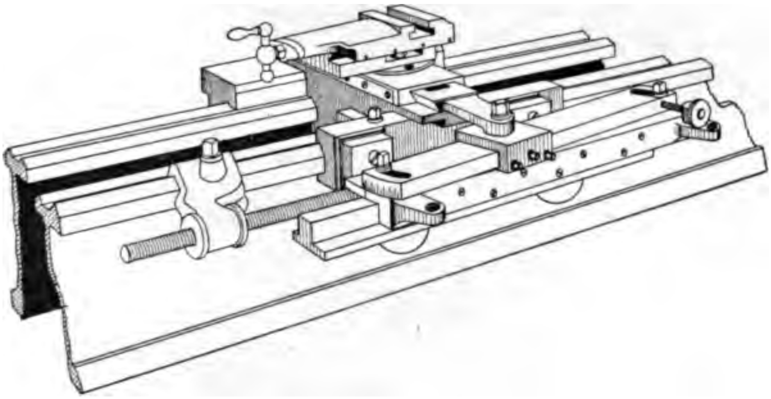


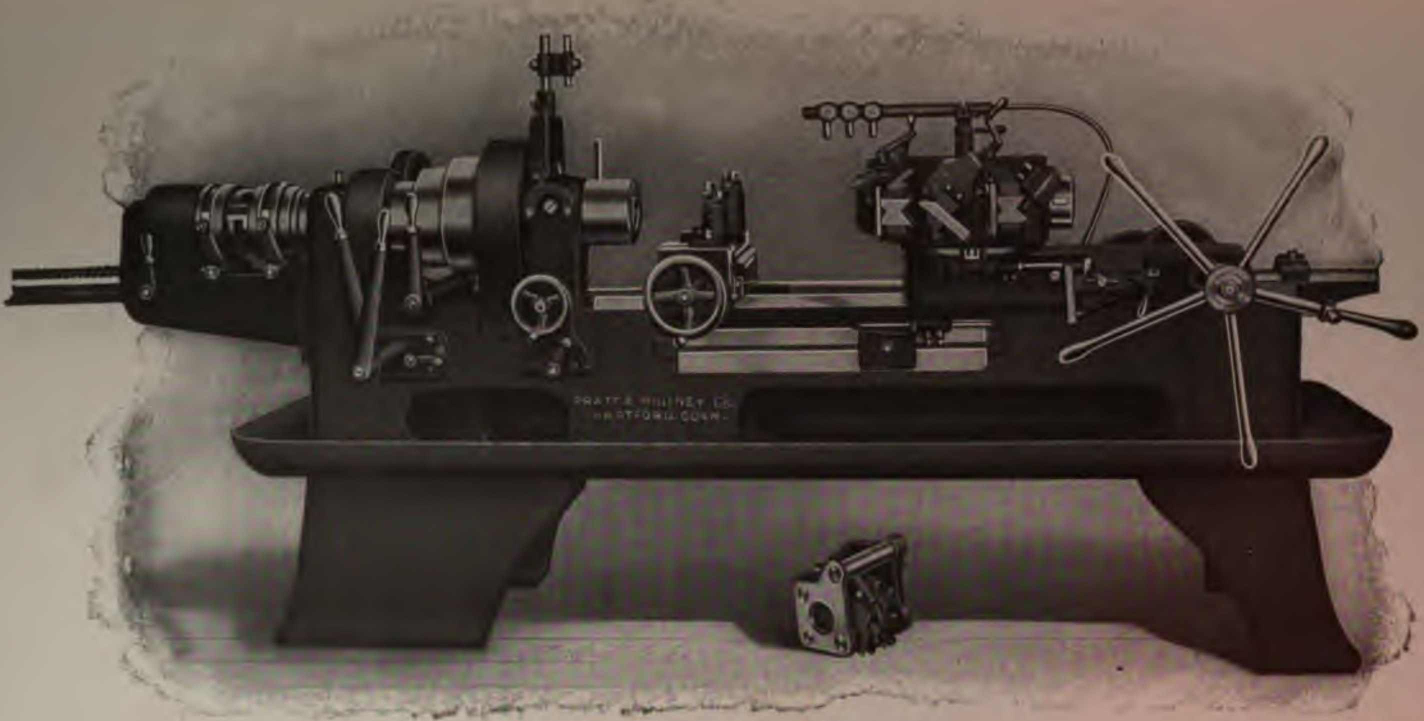
Fig. 140.

One of the most important points to be observed in turning tapers is to have the cutting point of the tool exactly level with the centers. If this is not done, the work will not be truly conical, and, furthermore, the rate of taper will vary with each succeeding cut.

In case an internal and an external taper are to be turned so as to form a fit, the internal taper should, if the character of the work will permit, be made first. After this has been done, the external taper should be turned and tested several times during the process. The external taper is first turned as accurately as possible, taking care that the piece be made a trifle too large. Draw a chalk line on the external taper, from one end to the other, press the tapers together, and give one of them a slight twist. On separating the tapers, the rubbing of the chalk will show where the work was in contact, and, by resetting the lathe and repeating the process, a very accurate fit can be obtained.

Shafting is usually turned $\frac{1}{16}$ inch less than the nominal diameter. For instance, instead of a shaft 2 inches in diameter, one of $1\frac{15}{16}$ inches in diameter is used. The reason is that iron of a nominal diameter of 2 inches, usually $\frac{1}{32}$ inch over size, can be used. Before turning a length of shafting, the rough bar should be carefully straightened. After the center holes have been drilled and the piece placed in the lathe, the work can be turned and the eccentric portions marked with chalk. When this has been done, the bar should be removed from the lathe and sprung back into true alignment. It is well to take two cuts for finishing shafting, one for the roughing cut and one very fine finishing cut. The tool for the latter part of the work should be kept flooded in oil, or a solution of sal soda. If the work is light, a tool-holder, carrying both the roughing and the finishing tools, should be used. This makes it possible to do the work in what practically amounts to the time of one cut.

As a length of shafting is likely to spring under the pressure of the tool, some method of preventing such action must be employed. A steady rest can be used. It is, however, inconvenient and must be frequently moved or it will stand too far, at times, from the tools. Furthermore, as the rough bar will neither be truly round nor concentric with the centers, it is necessary to turn "spots" for the center rest. This operation takes considerable time, owing to the fact that very light cuts must be taken in order to avoid springing the bar. The best method is to have a ring attached to the tool-holder; the internal diameter of this ring is that of the finished shaft. It is slipped over the tail-stock cen-



2 x 26-INCH TURRET LATHE
Pratt and Whitney Co.

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ASTOR, LENOX AND
TILDEN FOUNDATIONS

ter and follows the finishing tool. It must, of course, be rigidly fastened to the tool-holder. In this way the shaft is supported close to the tools; the ring also serves as a guage to measure the diameter of the shaft. If, for any reason, the tools turn to a larger diameter than the inside of the ring, notice is immediately served upon the workmen to that effect by the binding in the ring.

Eccentric Turning. Up to this point, the work described for the lathe has been of the kind in which the turning is done on work concentric with the lathe centers. There are other classes of work that are offset and for which special provisions must be made. Of course the surface being turned must always be concentric with the spindle.

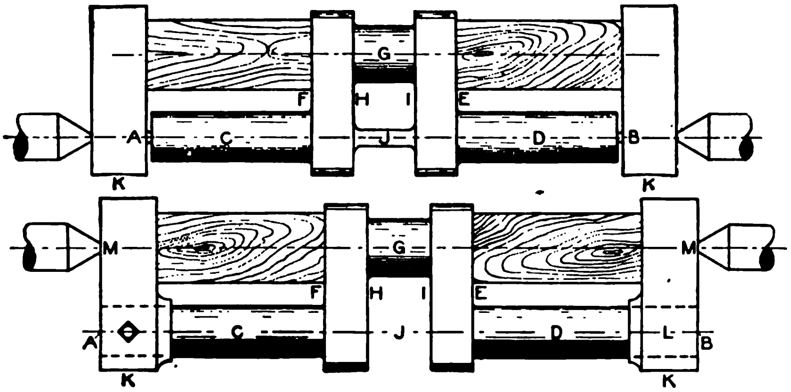


Fig. 141.

The turning of crank shafts presents conditions where there are two cylindrical portions, each parallel to and concentric with the lathe axis while being turned, but eccentric with regard to each other. In Fig. 141 such a shaft is shown. This may be either a casting or a forging. If cast, it is common to have a small web, shown at J, in the original casting to take the thrust of the centers while turning the shaft portions C and D. After centering the work at A and B, the shaft is placed in the lathe, and the ends A and B squared up, and surfaces C and D roughed out. If a forging is being worked, it will be necessary to insert a wooden block at the point J. Two lugs or ears K are provided to fit tightly on the rough turned shaft, the distance from the center of L to the center M being equal to one-half the throw of the crank. These lugs are attached to the ends of the shaft, so that a line joining the centers M will pass through the axis of the crank pin G. Blocks are now placed between the lugs and the crank pin, the web or block at J removed, and the pin turned on the new centers MM. The crank pin G is roughed and finished, and the shoulders H and I faced, at this time. Removing the lugs and blocks, the surfaces C and D are finished and the shoulders E and F faced on the centers A and B. If the shaft is of any considerable weight, it should be counter-balanced by attaching weights to the faceplate. The reason for not finishing the shaft at the first operation, is that removing the scale from a casting or the outer skin from a forging releases internal stresses which are likely to change the shape of the piece. As a general rule, a piece of work should be completely roughed out, if possible, before any finishing cuts are taken. The change in shape, due to the removal of the outer portion of the stock, does not all take place immediately; and, if very accurate results are desired, it is good practice to allow the roughed work to stand some time before finishing.

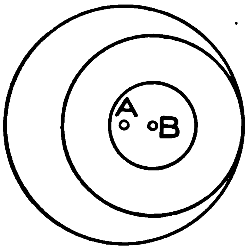


Fig. 142.

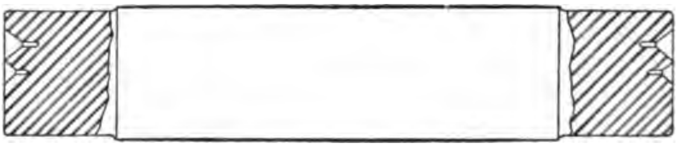


Fig. 143.

Turning an Eccentric. As far as its use in mechanism is concerned, an eccentric is the equivalent of a small crank, but it requires very different treatment in the lathe. In the first place, it is not usually made solid with the shaft, but is a comparatively thin casting or forging which is fastened to the shaft by set screws or keys. The general shape is shown in Fig. 142, and consists of the eccentric proper and a boss to reinforce the shaft hole; this boss usually being on but one side of the casting. In Fig. 142, A is the center of the eccentric and B the center of the shaft.

Small eccentrics, especially those having a throw less than the diameter of the shaft, may be finished in the following manner: The casting is grasped in an independent chuck, one having four jaws being preferred, with the boss or hub running as nearly true as possible. The projecting face of the eccentric, together with the outside and face of the hub, may be machined, and the hole can be trued up with a boring tool or by the use of the chuck drill and reamer. In either case, it is advisable to obtain the exact diameter by using a finishing reamer. The eccentric may now be placed on a special mandrel, shown in Fig. 143, which has an extra set of center holes. A line connecting these holes is parallel to the axis of the mandrel, and at a distance from it equal to one-half the throw of the eccentric. It is obvious that this mandrel is the equivalent of the shaft and lugs used in turning solid crank

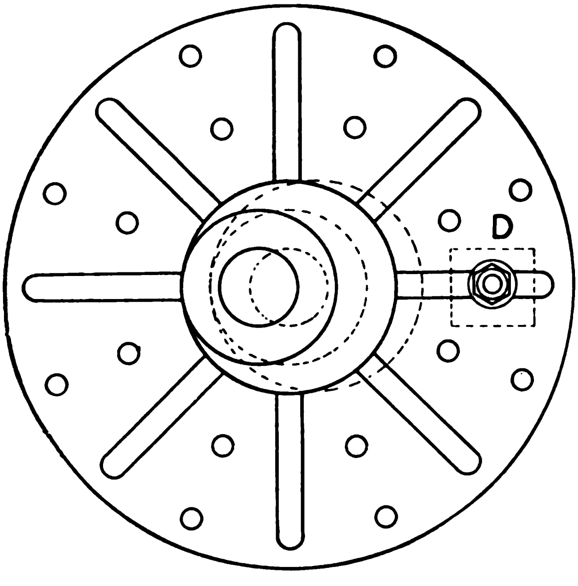


Fig. 144.

pins. On these extra centers the outside of the eccentric may be turned, and, on the regular centers, the back or plain face can also be finished. This completes the eccentric as far as the lathe is concerned.

Large and heavy eccentrics are preferably finished on a faceplate. The plain side or back having been previously machined, the eccentric is clamped to the faceplate with the hub running true, shown dotted in Fig. 144, and the face of the hub and the hole are finished as in the case of the small eccentric held in the chuck. The diameter of the hole being comparatively large, a reamer is not generally used. The eccentric is now moved on the faceplate a distance equal to one-half the throw of the eccentric, bringing the outer surface concentric with the lathe axis, as shown by the full lines, and the clamps placed so as to allow the outside to be turned. It is often necessary to balance the work by counterweights, in order to have the lathe run steadily. This is shown at D in Fig. 144.

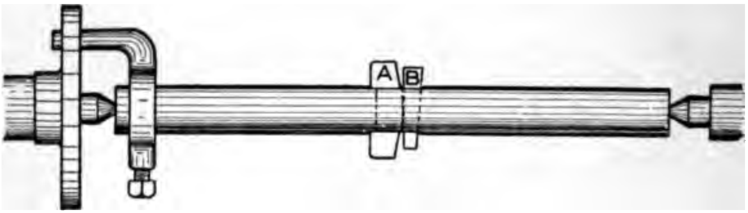


Fig. 145.

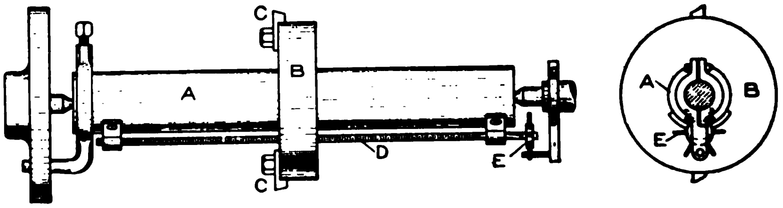


Fig. 146.

Boring. The boring of holes sometimes calls for a length and strength of tool that cannot be readily attained with the ordinary boring tool. A great deal of such boring is done with double-headed tools. These tools are held in bars and cut at each end. An ordinary form of such a tool is shown in Fig. 145.

The tool A is turned and fitted so that when placed in the bar it is central with the centers of the latter. It is held in position by the key B. It cuts at each end. Such a tool may be made to do very rapid work. It is extensively used for boring in places where a piece of work must be duplicated a great number of times.

Tools of this character are used for finishing. After the cut has been started the tool should not be stopped until the cut has been completed. If it is stopped there will be a ledge in the bore at that point. The reason for this is due to the springing of the metal and the contraction due to cooling while at rest. The tools used for finishing usually have a broad surface. Those used for the roughing-cut are narrower; they wear more rapidly than the finishing tools and are usually adjustable. A roughing tool may be held by a wedge as shown at B. Such a tool is placed in position and the wedge tightened just enough to hold it. The adjustment of the tool is then obtained by tapping it with the hammer. It is then held firmly by driving the wedge. An excellent example of this style of work is found in the boring of engine cylinders. Special machines are used for such work. The greater portion of it, however, is done in an ordinary lathe with a boring bar, as shown in Fig. 146. It consists of a heavy bar A, upon which there is a stiff traveling head B. The latter carries the tool C, which may or may not be capable of a transverse adjustment. The head moves longitudinally over the bar and is held,

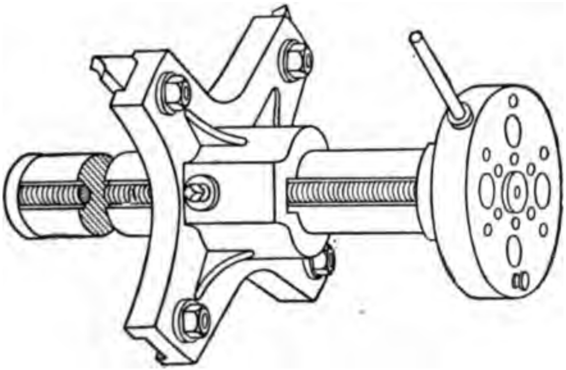


Fig. 147.

adjusted and fed by the screw D. At one end of the screw there is a star wheel, E, by which it is turned. As the bar revolves, one arm strikes against a stop at each revolution. This turns the screw by an amount proportional to the number of arms in the star. For example, if there are six arms in the star, the latter will be turned one-sixth of a revolution for each revolution of the boring bar. As the screw turns, it moves the head along the bar by an amount proportional to the pitch of its thread and the rays or arms in the star. This forms the feed of the tool. For example, if a star has four arms, and is keyed to a screw of eight threads to the inch, then for each revolution of the bar the head will be advanced $\frac{1}{32}$ of an inch. Another form of boring bar is shown in Fig. 147.

Boring bars with fixed tools are also used. In such cases the work is caused to travel beneath the bar as it is turned. A case of this kind occurs in the boring out of brasses for railroad cars.

It may be stated that, in general, all metal work should be finished in the position which it is eventually to occupy. This is due to its tendency to spring out of shape under the influence of its own weight. For small articles this influence is inappreciable. For large pieces it is sometimes quite apparent.

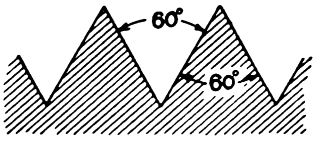


Fig. 148.

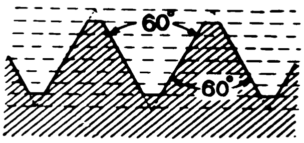


Fig. 149.

SCREW CUTTING.

The tools used for cutting threads are called *screw-cutting tools*. These tools are used in the lathe in the same manner as the diamond point and round-nosed tools. The cutting edge of the tool must be of the same shape as the space between the finished threads.

There are five types of screw threads commonly used in this country: the V thread, shown in Fig. 148, has the form of an equilateral triangle with an angle of 60°. It is sharp at the top and bottom. This thread is difficult to cut because of the trouble experienced in keeping the point of the tool sharp.

A modified form of V thread, known as the Sellers, the Franklin Institute, or the United States Standard, is shown in Fig. 149. This thread has an angle of 60°, with the top and bottom flattened for one-eighth of its depth. It is stronger than the V-shaped thread, and permits greater accuracy in cutting.

Another form in common use is the square thread. This is shown in Fig. 150. The thread and space are of the same width. These screws are used when heavy work is done, such as in jack-screws and presses.

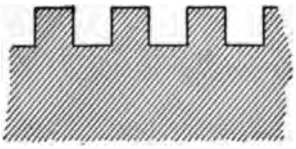


Fig. 150.

The Whitworth thread is similar to the United States Standard; the slight differences are as follows: the sides form an angle of 55° instead of 60°, and the top and bottom are rounded instead of flat.

The fifth type, the Acme thread, is similar to the square form. The difference is that the sides incline $14\frac{1}{2}°$ from those of the square thread. This form of thread is much used for lathe lead screws and for giving motion to sliding parts of fine instruments, because the thread is much stronger than the square form, and the lost motion can be taken up by simply closing the nut halves nearer together.

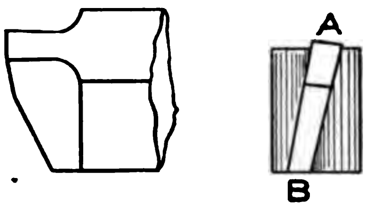


Fig. 151.

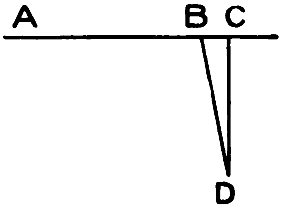


Fig. 152.

The tool used for cutting square threads is shown in Fig. 151. It is of the proper thickness at the cutting edge, but is somewhat narrower back of this point. The sides of the tool are inclined to the body, as shown at A B, Fig. 151; the amount of this inclination varies with the pitch of the thread and the diameter of the piece on which the thread is to be cut. To find the inclination, draw an indefinite straight line A C and at right angles to it draw C D. Make the length of C D equal to the circumference of the thread to be cut, measured at the root of the thread. On A C lay off from C a distance (B C) equal to the pitch; then draw B D. This line will represent the angle of the side of the thread. The angle of the side of the cutting tool must be a little greater for clearance.

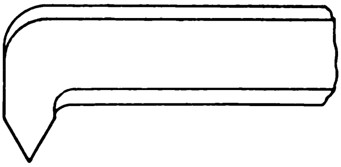


Fig. 153.

For cutting *inside* threads, the shape of the cutting edge of the tool should be the same as for cutting an outside thread, but the tool must be made so that the cutting edge alone touches the work. This is accomplished by bending the tool as shown in Fig. 153 and giving it considerable clearance.

Standard Screw Threads. When screw threads are to be cut, the pitch used depends upon the outside diameter of the bar. A standard has been adopted by all of the leading technical societies of the United States, and is known as the United States Standard. The table (see opposite page) gives the outside diameter of the screw from ¼ inch to 6 inches in diameter, with the number of threads per inch to be cut.

In placing the tool for any form of thread, the point of the tool must be exactly level with the center, and a line at right angles to the axis of the lathe must bisect the angle of the tool point. In order that these conditions may be fulfilled, a thread or center gauge, Fig. 154, is used. In this tool, the angles, A, B, and C are made exactly 60°. The two opposite sides are parallel. The angle A at the end is used for grinding the tool. The sides of the latter are made to touch all along the edge. For setting the tool, the upper parallel side is held against the face of the work in a

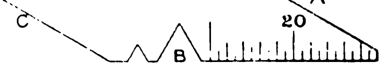


Fig. 154.

horizontal position. The tool is then set so that its sides touch along the edges of the notch B. The angle C is used to gauge the thread after it is cut.

UNITED STATES STANDARD SCREW THREADS.

DIAMETER OF SCREW IN INCHES.	NUMBER OF THREADS PER INCH.	DIAMETER OF SCREW.	NUMBER OF THREADS PER INCH.
1/4	20	2	4 1/2
5/16	18	2 1/4	4 1/2
3/8	16	2 1/2	4
7/16	14	2 3/4	4
1/2	13	3	3 1/2
9/16	12	3 1/4	3 1/2
5/8	11	3 1/2	3 1/4
3/4	10	3 3/4	3
7/8	9	4	3
1	8	4 1/4	2 7/8
1 1/8	7	4 1/2	2 3/4
1 1/4	7	4 3/4	2 5/8
1 3/8	6	5	2 1/2
1 1/2	6	5 1/4	2 1/2
1 5/8	5 1/2	5 1/2	3 3/8
1 3/4	5	5 3/4	2 3/8
1 7/8	5	6	2 1/4

The measurement of fine threads is a difficult matter where an ordinary rule is used and the threads between the inch marks are counted. For this purpose a pitch gauge, Fig. 155, is used. The gauges are short screw sections on thin sheets of metal. To ascertain the pitch of any thread, set the gauges over it successively until one is found that exactly fits. The figures stamped thereon will give the number of threads per inch.

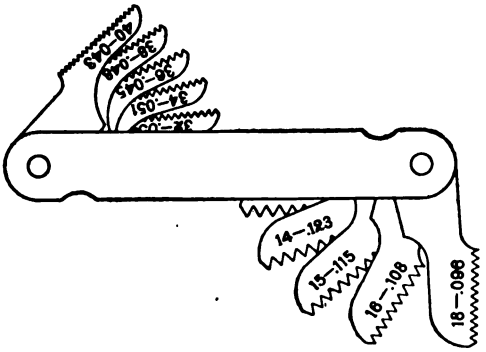


Fig. 155.

The cutting of a thread demands that there shall be a certain definite ratio of motion between the rotation of the work and the travel of the carriage. When a right-handed screw is to be cut, the carriage travels from right to left. For example, if a screw having a pitch of ¼ inch, or with four threads to the inch, as it is usually expressed, is to be cut, the spindle must make four revolutions while the carriage is moving one inch along the bed. If the screw is to have eight threads to the inch, the spindle must make eight revolutions to each inch of motion of the carriage or tool; if six threads, then six revolutions to the inch of motion, etc.

If, then, the lead screw is cut with four threads to the inch, it is evident that the speed of rotation of the spindle and of the screw must be the same, in order to cut a screw of four threads to the inch. For each revolution of the lead screw, the carriage moves the distance of the pitch of the same or ¼ inch. Hence, the gears, J and L, Fig. 91, must have the same number of teeth. When a screw of eight threads per inch is to be cut, the spindle must make twice as many revolutions as the lead screw. Then, for each revolution of the spindle, the lead screw makes half a revolution and thus moves the carriage ⅛ inch. In this case, the screw gear L must have twice as many teeth as the spindle gear J. For six threads, the ratio of revolutions between spindle and screw is 1½ to 1. This requires 1½ times as many teeth in the screw gear L as in the spindle gear J.

The rule for finding the gears to be used on the spindle and lead screw is: Multiply the number of threads on the lead screw and the number of threads to be cut by the *same* number; the products will equal the numbers of teeth on the gears to be used.

Suppose the lead screw has four threads per inch, and ten threads per inch are to be cut. Multiply both numbers by any convenient number, such as 3. Then the gears should have 12 teeth and 30 teeth.

Let a = the number of threads per inch on the lead screw,
b = the number of threads per inch to be cut,
c = a convenient number,
$a\,c$ = the number of teeth of gear on spindle,
$b\,c$ = the number of teeth of gear on lead screw.

If the gears thus found are not at hand, multiply by some other number. Thus, suppose gears of 30 and 12 teeth were not available, multiply 4 and 10 by 4 or by 5 or any other number that would give the number of teeth on the gears at hand.

Another way to find the gears is to remember that the number of threads to be cut is to the number on the lead screw as the number of teeth on the screw gear is to the number of teeth on the spindle gear.

EXAMPLES FOR PRACTICE.

(1) The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 9 threads to the inch? If one gear has 24 teeth, how many should the other have?

Ans. { 1: 2¼
54 teeth.

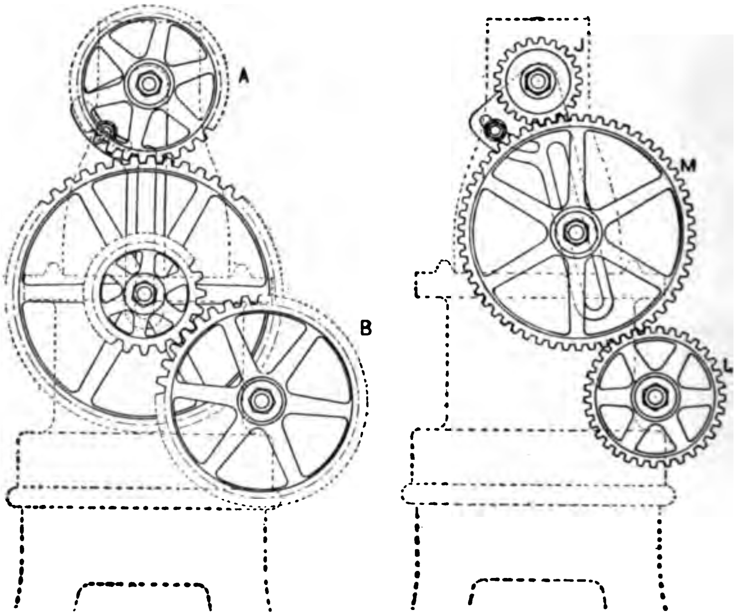
(2) The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 16 threads to the inch? Ans. 1: 4.

(3) The lead screw has a pitch of ⅓ inch. What is the ratio of gears to be used to cut a screw with 12 threads to the inch? Ans. 1: 4.

In these cases the actual number of teeth on the gears to be used is obtained by multiplying the ratio by some common multiple. Thus in example 1, multiplying by 10 gives 40 teeth for the spindle gear and 90 for the screw gear. In example 2, multiplying by 20 gives 20 teeth for the spindle and 80 for the screw gear; and the same result is obtained by using the same multiple for example 3.

Every screw-cutting lathe is provided with a set of gears from which selections can be made. In order to facilitate the choice of the gears to be used, a *gear table* is usually cast in raised letters and screwed to the front piece of the headstock. This table shows the gears to be used for cutting such threads as may be enumerated on the table.

It is sometimes necessary to cut a screw for which there are no gears to make a direct connection. This necessitates the compounding of the gears on the intermediate spindle to replace the single gear. This is done as shown in Fig 156, in which A represents the spindle and B the screw. Suppose, with a lead screw having three threads to the inch, it is desired to cut a screw having thirteen. This makes the ratio of teeth on the spindle gear to those on the screw as 3 to 13. The work can be done with spindle gears having 15, 30, or 45 teeth with screw gears having 65, 130, and 195 teeth respectively. If it is found that there are no gears having 15, 45, 130, or 195 teeth on hand, compounding must be resorted to. To determine the gears to be used it must be remembered that *the product of the numbers of teeth in the driving gears must be to the product of the numbers of teeth of the driven gears, as the number of threads per inch on the lead screw is to the number to be cut.* In this case it is as 3 to 13. Multiply each of these figures by any convenient multiple. In the example in hand, let the multiple be 200. Then



Compound Gear. Fig. 156. Simple Gear.

$$\frac{3 \times 200}{13 \times 200} = \frac{3 \times 2 \times 2 \times 2 \times 5 \times 5}{13 \times 2 \times 2 \times 2 \times 5 \times 5}.$$

Select from the factors thus obtained two sets, each of which, when multiplied together, will give products equal to the number of teeth that are on hand.

Thus in the numerator we may take 3 × 2 × 5 and 2 × 2 × 5, giving 30 and 20 as gears that are to be used as the spindle and intermediate drivers respectively.

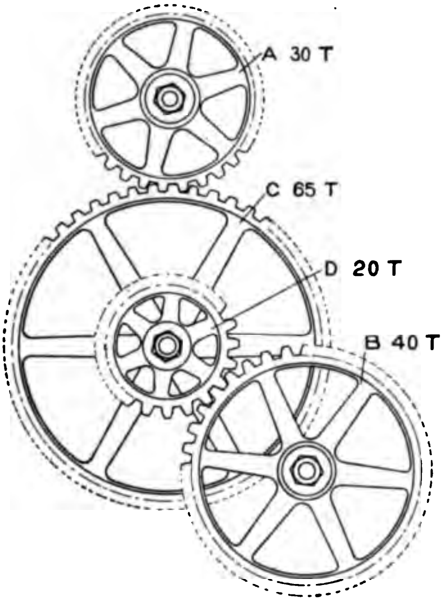


Fig. 157.

For the denominator take 13 × 5 and 2 × 2 × 5 × 2 or 65 and 40, for the driven gears of the intermediate stud and the screw respectively. Placing these in position as in Fig. 157, we have,

Gear A with 30 teeth.
Gear C with 65 teeth.
Gear D with 20 teeth.
Gear B with 40 teeth.

It is desired to cut a screw with 11 threads to the inch on a lathe having a lead screw with a pitch of ¼ inch. The gears available have 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, and 100 teeth respectively. What ones are to be used and where?

Ans.	Spindle	40 teeth
	Intermediate driven	55 teeth
	Intermediate driver	50 teeth
	Screw	100 teeth.

Many screw-cutting lathes are not made with an extension of the spindle to receive the first gear, but a short shaft or stud projects from the headstock for this purpose. This stud is geared to the spindle, and the ratio of this gearing must be considered when calculating the gears for screw-cutting. For example, suppose we wish to cut twelve threads per inch in a lathe having a lead screw with eight threads per inch and a ratio of two to one between the spindle and the stud. In other words, the stud runs half as fast as the spindle. As we have seen in the previous examples, the ratio between the spindle and the lead screw must be 12 to 8

The first gear is not attached to the spindle, but to the stud, which makes six revolutions to twelve of the spindle. Therefore, the ratio between the stud and the lead screw, where the gears are actually applied, must be 6 to 8. Multiplying by 6 will give 36 and 48 as the number of teeth in two gears which may be used.

In general, the data that must be given to calculate the change gears for screw-cutting are the number of threads per inch to be cut on the work, the number of threads per inch on the lead screw, and the speed ratio between the spindle and the stud, if a stud is used.

The following examples may be taken as applying to either right- or left-hand threads. The change of direction in the travel of the carriage is obtained by introducing an extra gear into the train, thus reversing the rotation of the lead screw.

The following description of the method of cutting a "V" thread will suffice to illustrate the cutting of any form, with the slight changes which are necessary in the other forms due to the shape of the tool employed.

To cut an ordinary V thread, a V-pointed tool having an angle of 60°, and set so that a line at right angles to the lathe axis bisects the tool angle, and also set exactly at the height of the center, is caused to move at a constant rate parallel to the work surface, while the work is being uniformly rotated.

The relation between the rotary motion of the work and the lateral movement of the tool, determines the pitch of the thread being cut, and the mechanism connecting the work and the tool must be of a positive character; thus eliminating transmission by belts and other frictional devices.

Owing to the lost motion or "back lash" in the mechanism connecting the tool and the work, the tool cannot be returned to the starting point for a new and deeper cut by simply reversing the lathe. The tool must be withdrawn, the lathe reversed, the tool returned to the starting point, and then advanced for the new cut. To place the tool for the new cut with accuracy, a stop or graduated device is provided.

If removed from the lathe for testing, care should be taken in replacing the work to get the tail of the dog in the same slot in the face plate that was used to cut the original thread; this can be done by marking or otherwise indicating it.

Chasing. The ordinary methods of cutting screws have already been described. Where great accuracy is not necessary. the threads may be chased by hand. A chaser, or chasing tool, differs from the ordinary thread-cutting tool, in that it has a number of cutting points instead of but one. When a chaser is operated by a power feed, it is customary to have a shaft revolving at the same rate or at an even multiple of the rate of the lathe spindle. This shaft carries a master thread into which a section of a nut drops. The handle connected with the nut carries the chasing tool. When the nut is in contact, the tool is cutting. At the end of the cut, the tool is lifted out, and with it the nut disengages with the thread.

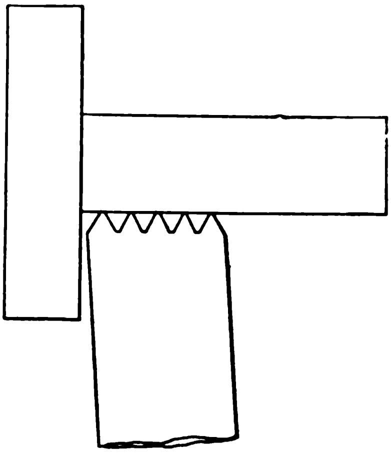


Fig. 158.

Hand-chasing requires a great deal of skill in order that a good piece of work may be done. The chasing tool has a number of points as shown in Fig. 158. The work must be run rapidly in the lathe. The tool is held in both hands, and is supported on a rest similar to that shown for the hand-turning tools in Fig. 86. The first left-hand tooth of the chaser is brought lightly against the right-hand edge of the work. The handle is given a quick twist from left to right throwing the teeth in the opposite direction. It is well after the first twist, to stop the lathe and examine the

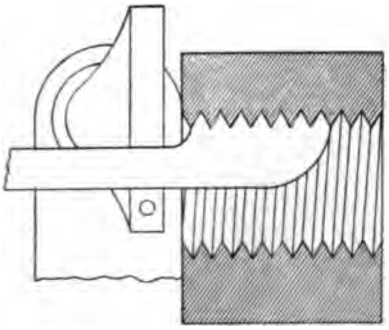


Fig. 159.

work. If the operation has been properly performed, the second tooth will be found to have entered the groove made by the first. A short length of thread will have been cut, the pitch being the same as that of the chaser. If this is correct, the lathe may again be started and the chaser applied as before. On the second trial the thread may be run to its full length. The finishing of the thread is done by merely repeating the operation. A fine cut is taken with each application of the chaser for the whole length of the thread until the full depth has been cut. In doing this work, the rear or right-hand side of the chaser should be pressed more firmly against the piece being cut than the front, because the threads with which that portion of the tool is engaged are more deeply cut than at the front. In addition to cutting, these teeth also guide the front. The reason for running the lathe at a high rate of speed, is that the movement of the chaser is less likely to be checked or thrown aside by seams or inequalities in the density of the metal than it would be if the lathe were to run slowly. Inside threading may be done by means of the inside chaser shown in Fig. 159.

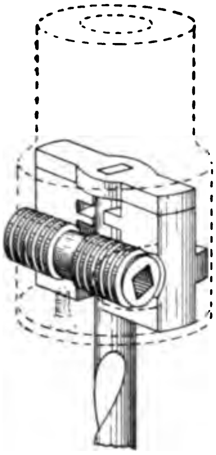


Fig. 160.

Drilling in the Lathe. The lathe can also be used for drilling. When such work is to be done, the drill may be held in the spindle and the work forced up against it by the screw of the tail stock: or the work may be revolved and the drill forced in by the tail-stock screw. When the first method is followed the drill may be put into a socket prepared for it in the spindle of the lathe, or the drill may be held by a drill chuck as shown in Fig. 160. This chuck may be used in the tail-stock to hold twist drills, or to hold flat drills which are forged from round stock. Flat drills made from flat stock are centered at the rear end and held against, and fed forward by, the dead center. In this case, a slotted rest held in the tool post prevents the drill from turning (see Fig. 60) and aids in starting the drill true.

When the drill is held in the head stock, the work may be

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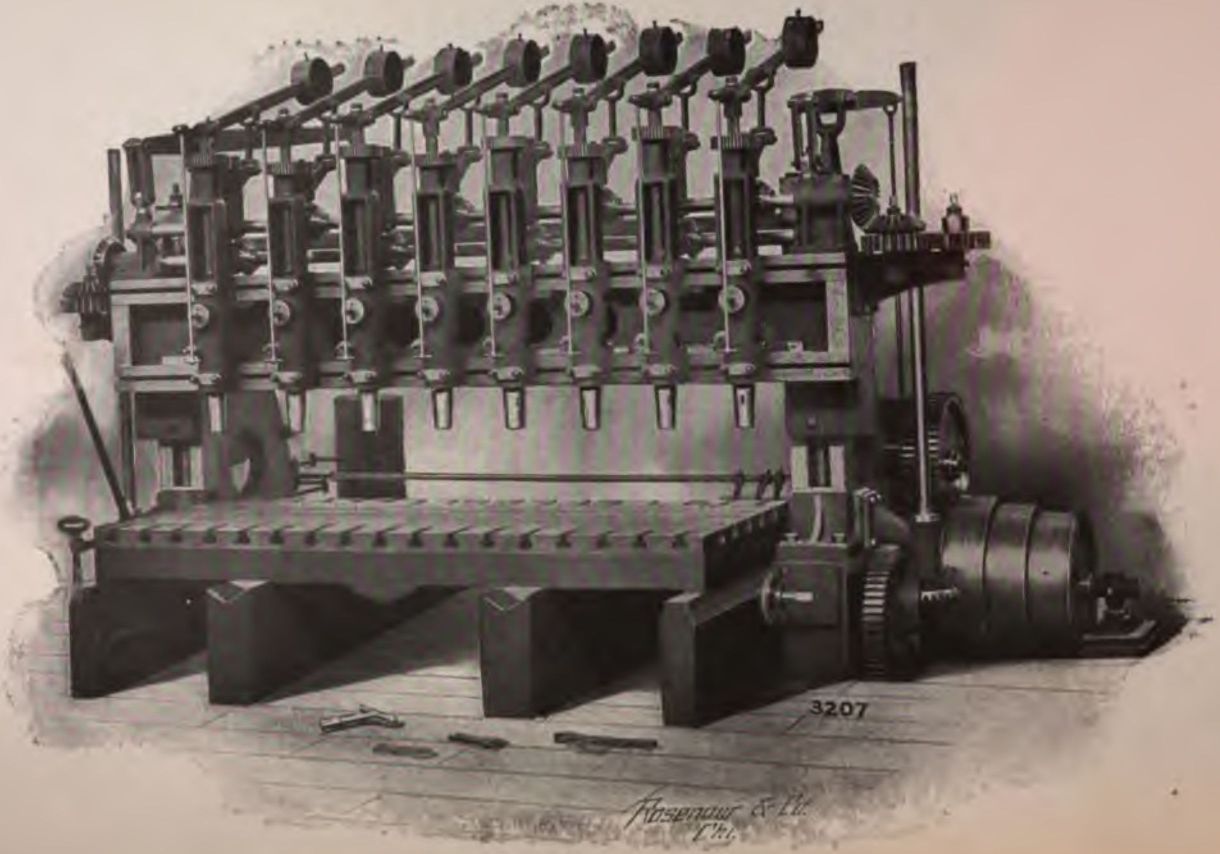

MULTIPLE DRILLING MACHINE.
Niles-Bement-Pond Co.

fastened to the carriage and fed against the drill, or it may be held by means of a suitable device held in the tail stock. For this purpose the drill pad, shown in Fig. 161, may be used, and especially if the work be flat. The V center, shown in Fig. 162, is used when it is desired to drill through the axis of a piece of round stock. The shape of the groove prevents the work from turning and the angle being always in the axis of the lathe determines accurately the location of the hole.

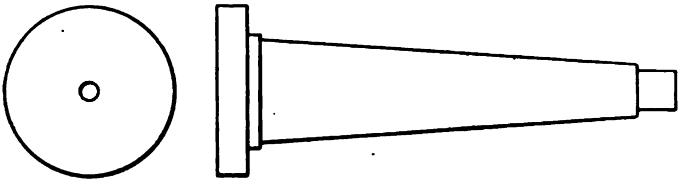
Fig. 161.

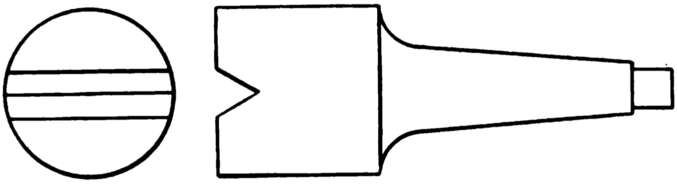
Fig. 162.

THE DRILL PRESS.

This tool is made in a great variety of forms, according to the class of work it is intended to perform. The form illustrated in Fig. 163 is one of the standard makes. The mechanism is very simple and will be briefly explained.

The frame consists of a strong column A, securely bolted to a heavy base-plate B. Power is delivered to the machine by means of a belt running over the cone pulley C. The shaft upon which this cone pulley turns, runs through the casing D, where, by means of miter gearing, it drives the vertical drill spindle E. It will be seen that there are four steps on the cone pulley C, thus affording a means for securing as many rates of revolution of the drill spindle. This, however, is not sufficient to meet all the

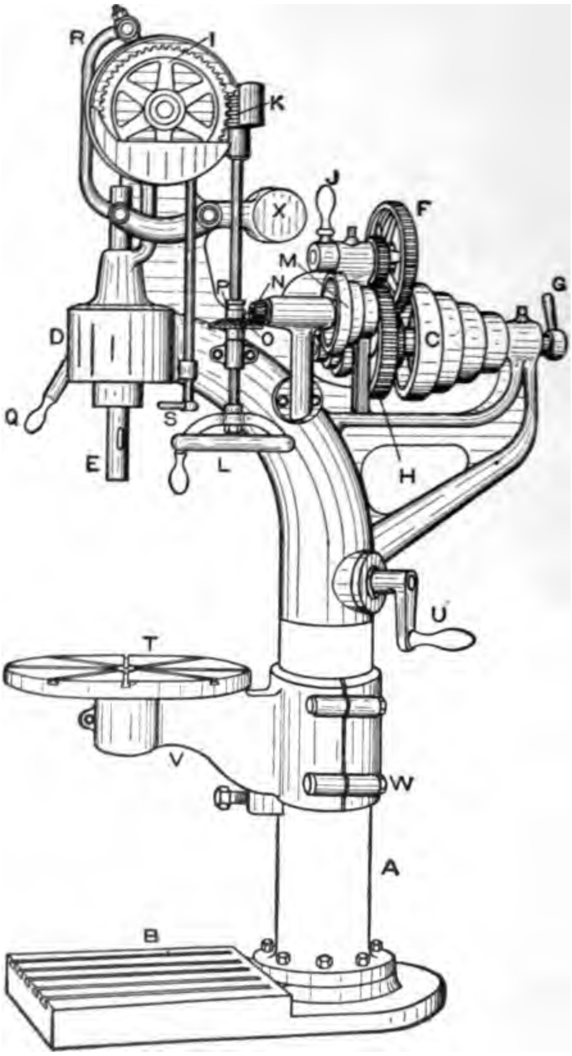

Fig. 163.

requirements of the work that can be done with the tool. In order to increase the range of available speeds, a *back gear* is used. This is shown at F. It consists of a gear and pinion keyed to the same shaft. The cone pulley C is loose on the horizontal shaft, but may be fastened to it by a clutch operated by the lever G. The inner end of the cone pulley carries a pinion that meshes with the gear F, while the pinion attached to F meshes with the gear H that is keyed to the horizontal shaft. The gear F and its pinion run loosely on a journal that is, in turn, attached to an eccentric bearing. By turning the handle J, which is attached to the eccentric bearing, the gears may be thrown in or out of mesh. While the gears are in mesh, the power passes from the cone pulley to the pinion attached to it, to the gear F, to its pinion, and thence to the gear H, and thus turns the shaft. Under these circumstances the shaft is turning much slower than the cone pulley.

The feed; or downward motion of the drill spindle may be accomplished by hand or by power. At the upper end of the drill spindle a rack is cut, into which a pinion on the same shaft as the worm wheel I meshes. It is evident that, as this wheel revolves, the spindle will be raised or lowered.

The weight of the spindle is counterbalanced by the weight X. The worm wheel I is turned by the worm K, which is rotated by the hand wheel L. This serves for a hand feed. For a power feed, a belt is made to drive the cone wheel M. This turns the bevel pinion N, meshing with the bevel gear O, that is loose on the feed shaft. It is fastened to the latter by means of a small clutch P. A quick return of the spindle is accomplished by means of the handle Q. This is attached to the spindle by means of a yoke R. When the quick return is to be used, the worm K is thrown out of mesh with its wheel by turning the handle S.

The table T may be raised or lowered by means of the handle U; this drives a screw in the standard running in a nut fastened to the bracket V. When the table has been adjusted, it may be fastened by the nuts and bolts W clamping it to the standard A. When large work is to be drilled, the table may be swung out of the way and the work bolted to the base plate B.

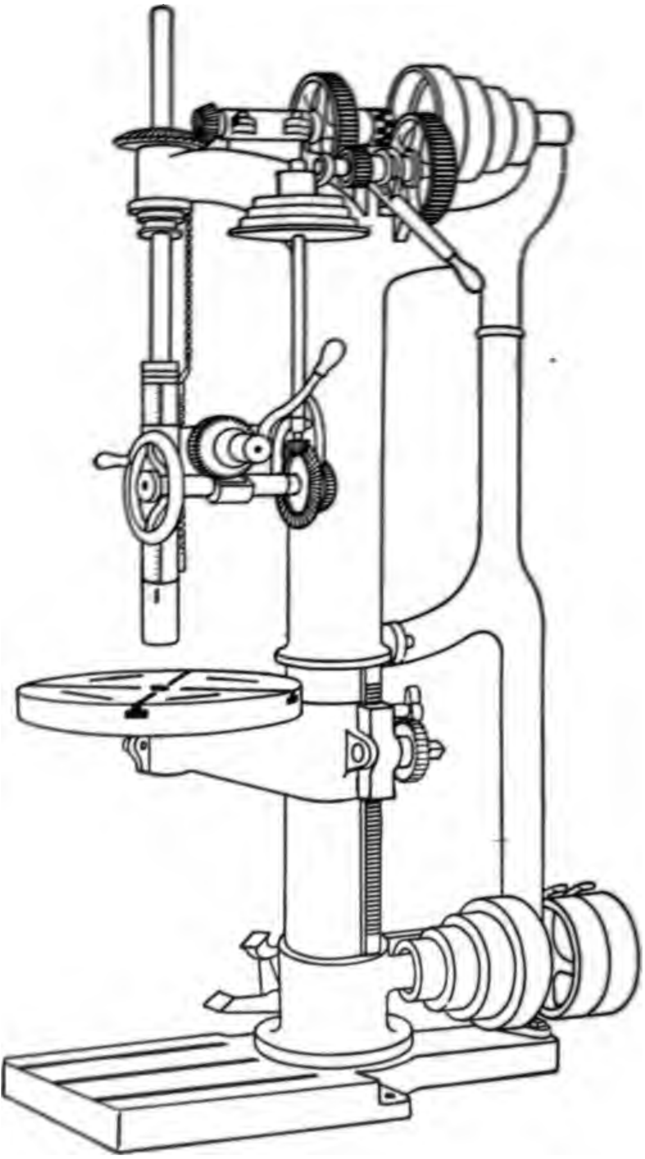

Fig. 164.

While the drill press just described may be taken as representing good practice in the smaller sizes, a different form of construction is often employed in larger tools. A drill press of this class is shown in Fig. 164. Drilling machinery is made both horizontal and vertical. A typical form of the horizontal variety is shown in Fig. 165. These tools are usually of heavier construction and for a larger class of work than the ordinary vertical drill.

Drilling machinery, both horizontal and vertical, is sometimes provided with more than one spindle. In small vertical drills of this description, the spindles are fixed in their relative positions and are not intended to be operated simultaneously; the work is passed from one spindle to another. The true multi-spindle drill is for the purpose of drilling several holes at one time and in any relative position within the limits of adjustment of the machine. Such a drill is shown in Fig. 166.

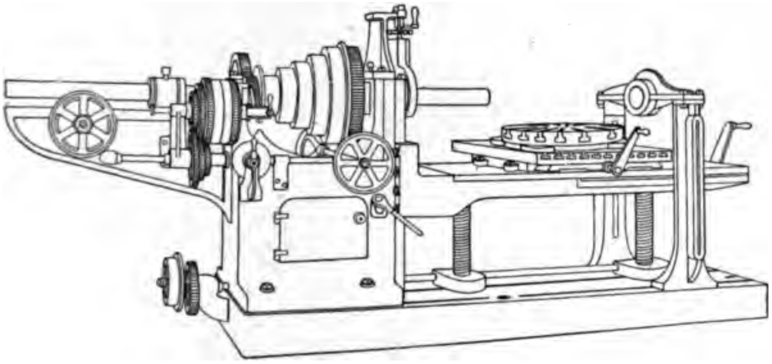
Fig. 165.

The Radial Drill. Another form of drill, known as the radial, is being extensively used. It is shown in Fig. 167.

The drill spindle is carried on the arm A. It is so arranged that it can be set and run at any position on this arm. At the same time, the arm may be swung around and clamped in any vertical or horizontal position about the upright B. These drills are usually employed on heavy work, where a number of holes are to be drilled.

In the case of the drill shown in Fig. 163, the work is ordinarily light, and can be readily shifted so that the position of the holes can be brought beneath the drill. In heavy work, such as engine cylinders, however, this cannot be done. It is, therefore, necessary to be able to shift the drill and place it in a position to do the work. The radial drill affords the means of doing this. When the vertical spindle carrying the drill can be rotated in the vertical plane, holes can be drilled, not only in any position, but also at any angle. Such a drill is called a Universal Radial.

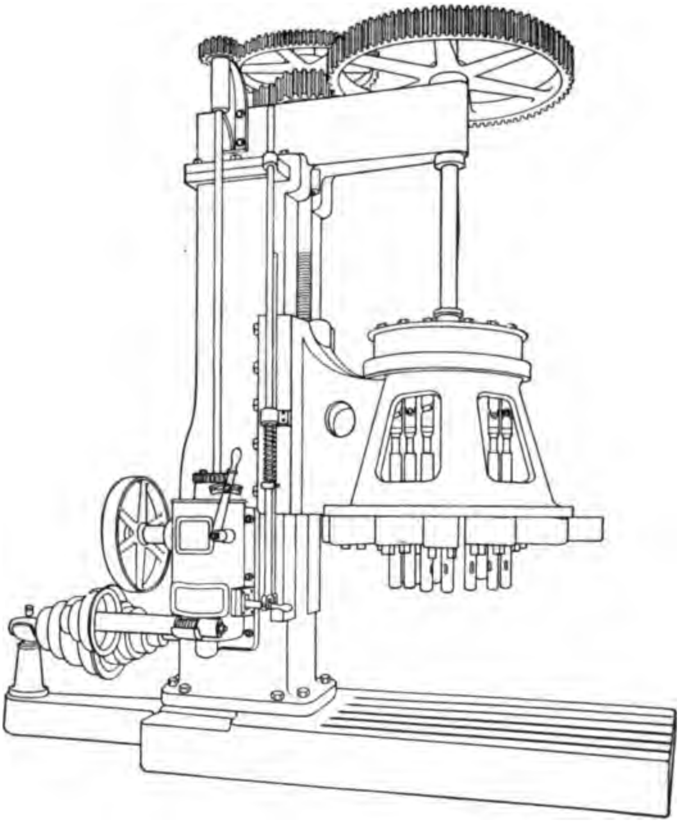

Fig. 166.

The position of the holes is usually laid out for the guidance of the man at the drill. The work is best done as shown in Fig. 168. The center punch mark, indicated by A, shows the location of the center of the hole. The circle upon which the prick punch marks BBBB are placed, gives the location of the circumference of the hole. To drill the hole, place the point of the drill in the center punch mark A, and drill into the metal until the center punch mark has been slightly enlarged, as shown by the circle C, Fig. 168. Then raise the drill and examine the work. If the countersink or hole, whose circumference is indicated by the circle C, is exactly concentric with the outer circle BBBB, then the drill may be put down and the hole drilled.

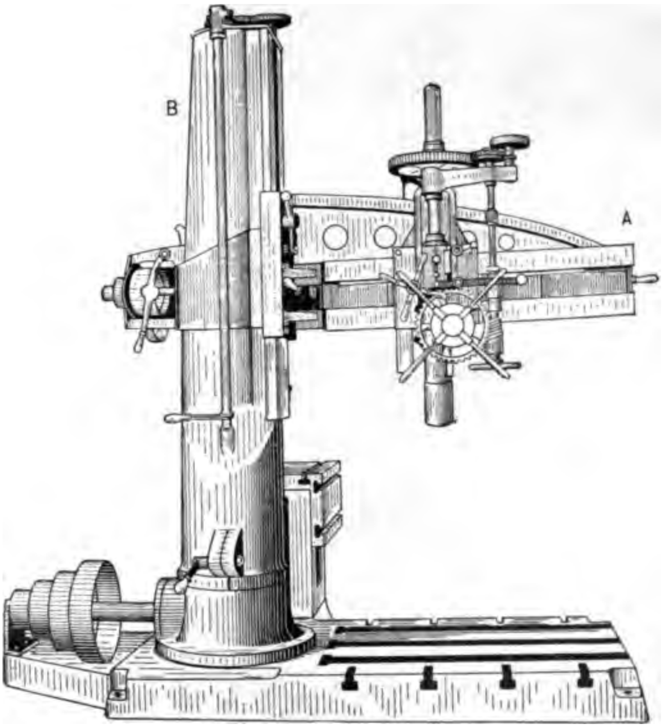

Fig. 167.

Owing, however, to various causes, it is not often that the circle will be concentric. This may be due to an uneven grinding of the drill, a distortion of the metal by the center punch, or an eccentric motion of the drill point, due to a lack of truth in the running of the spindle.

When the countersink is not concentric, the drill must be drawn back to the central position. The method employed is shown in Fig. 169. The round-nosed chisel is used to cut a groove, E, down the side of the countersink, on the side that is farthest from the circle BBBB. The depth of this groove depends upon the amount of eccentricity of the countersink and the depth to which it has been drilled. The drill is then run down again and the groove drilled out. The action of this groove is as follows: as the drill turns, one cutting edge is supported, and is working into the face C, Fig. 170. At the same time the cutting edge is opposite the groove E. The drill, therefore, springs into the groove, as shown. The lip then catches on the edge of the groove and cuts it away, making the hole elliptical, and shifting the center of the drill towards its proper position. As the drill sinks deeper both lips are in contact with the faces C and D, and it has no further tendency to shift.

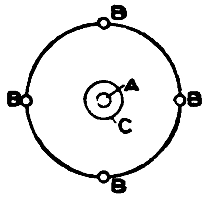

Fig. 168.

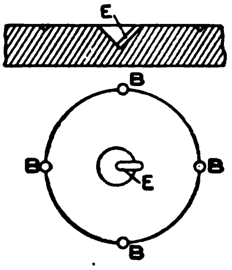

Fig. 169.

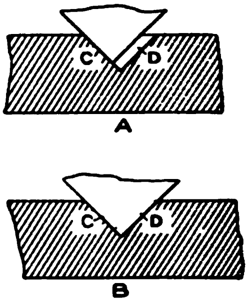

Fig. 170.

When the groove has been drilled out, the drill must be again raised, to ascertain whether or not the countersink is concentric with the outer circle BBBB. If not, another groove must be cut, and the process repeated. If it is, the hole may be drilled. The prick punch marks BBBB are put on the outer circle to indicate its position in case of the obliteration of the line itself.

A twist drill will usually clear its hole of chips. For deep holes this may not occur. It is then necessary to withdraw the drill and clean out the hole. This can be done by a piece of wire bent at the end; also by using a "blowpipe" made of a small tube, and bent to enter the hole, so that the chips will not blow up into the operator's face. Cast iron is more likely to need cleaning than wrought iron or steel. Where flat drills are used, it is always necessary to clean the holes at frequent intervals, as they have no tendency to raise the chips and clear the holes.

A matter to receive due consideration is that the work must be held rigidly on the table while being drilled. This may be done in two ways. If the holes are to be drilled with great accuracy, the work must be clamped to the table. This is often done by means of straps, as shown in Fig. 171. In this figure, a gland A is shown clamped to the table by the straps BB. One end of the strap rests upon the flange of the gland, and the other upon any convenient piece of metal C, of the proper thickness. The bolt D is put up through a hole in the table as close to the work as possible. When the nuts are screwed down, they then put the greatest available pressure on the work and hold it fast. The strap B is made of flat iron. It has one or more holes drilled in it to permit the passage of bolts.

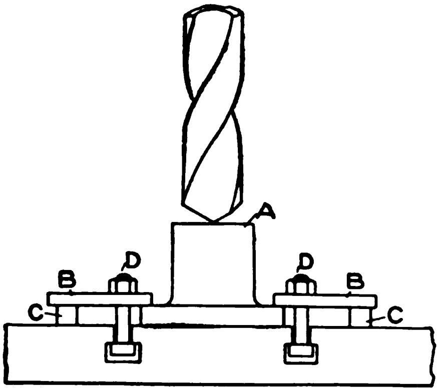

Fig. 171

Another method of holding work in the drill press is by means of a post. This is shown in Fig. 172. It consists of a post A, set loosely in one of the holes in the table. As the drill is forced against the work, it tends to turn the latter with it. When the work strikes the post, it is stopped and held while the hole is drilled. This will not hold the work perfectly steady. It allows the latter to move with the eccentricity of the motion of the drill, but it is in very common use where extreme accuracy is not essential. For example, where a finished bolt is to be used with a driving fit, the work must be securely fastened so that the diameter of the hole may be true. Where a machine bolt made of rough iron is to be used, the hole is drilled $\frac{1}{16}$ inch larger than the normal size of the bolt. Here accuracy is not even attempted; a variation of $\frac{1}{32}$ inch in the diameter of the hole is of no account. Therefore, in such cases, the work may be allowed to merely rest against the post.

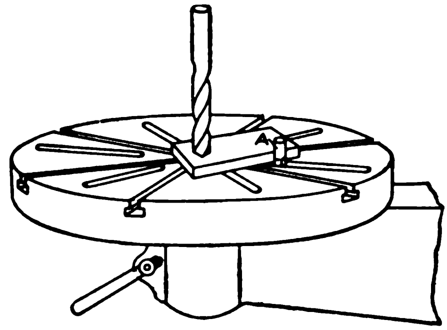

Fig. 172.

This question of holding the work does not apply to drills of the multi-spindle class. It is evident that the tendency of one drill to rotate the work is *counteracted by the action of another drill.* Therefore, no holding devices are needed on drills of more than one spindle.

An angle iron, forming a right angle with the drill table, is used in many cases where the hole cannot be properly located by the use of the table alone. The clamping to the angle iron must be very rigid to resist the pressure of the drill. A tilting table is sometimes used so that holes may be drilled at any required angle. At least one manufacturer is putting on the market a horizontal drilling machine which can drill five sides of a cube at any angle with but one setting of the work.

Drilling machines may also be used for tapping. This requires a reversing device for backing out the tap. The backing-out is done at a much higher speed than the tapping. The tap is held in a friction head that will slip when the tap strikes the bottom of the hole. The use of collapsing taps, especially on diameters of one inch and over, renders the backing-out unnecessary and quickens the operation. Studs may be set by the same device, so that cylinder flanges may be drilled, tapped, and the studs set without removing the work from the drill. Duplicate drilling by means of jigs will be considered later.

THE PLANER.

Next to the lathe, the planer is the most important tool in the machine shop. As the name indicates, it is used for finishing flat surfaces. In the ordinary planer, the work is moved and the tool is at rest. A common form of this tool is shown in Fig. 173. It consists of a bed A upon the upper surface of which suitable guides or ways are planed. The platen B is made to travel back and forth upon these ways. The platen has a rack on its under surface into which the gear C meshes. This gear is driven by a train of gears from the shaft carrying the pulley D. The tool is carried on the tool-head E, where it can be given a slight vertical motion or feed. This tool-head may be fed across the machine by the screw in the cross-rail F. The latter may be raised and lowered by the shaft and gearing shown at the top. This gearing turns two vertical screws running in nuts attached to the cross-rail.

The reciprocating motion of the platen is obtained as follows: the pulleys D and G are driven in opposite direction by belts. Either one may be connected to the shaft on which they turn by a clutch which is operated by the bell crank lever J. On the platen there are two adjustable dogs HH. These are set so that, when the work has just cleared the tool in either direction, one of them will strike against the upper end of the lever I. In the illustration, if the platen is moving in toward the right-hand dog, H will have struck the lever. As the platen continues to move, the lever I is carried to the right and the clutch connection fastening the forward pulley to the shaft broken and that of the return made. The motion is then reversed and continues until the left-hand dog strikes the lever I and again changes the motion.

Ordinarily the tool cuts only when the platen is moving toward the right Fig. 173. As a result of this condition, the platen is made to move more rapidly in the direction of the arrow than in the reverse. This is accomplished by varying the speeds of the pulleys D and G. The usual ratio of the speeds of these pulleys is from 1 to 2, to 1 to 5.

The feed of the tool is accomplished by a friction clutch driving the vertical rack K. This acts only at a point near the end of the travel of the platen. It is so arranged that any vertical or horizontal feed may be given to the tool.

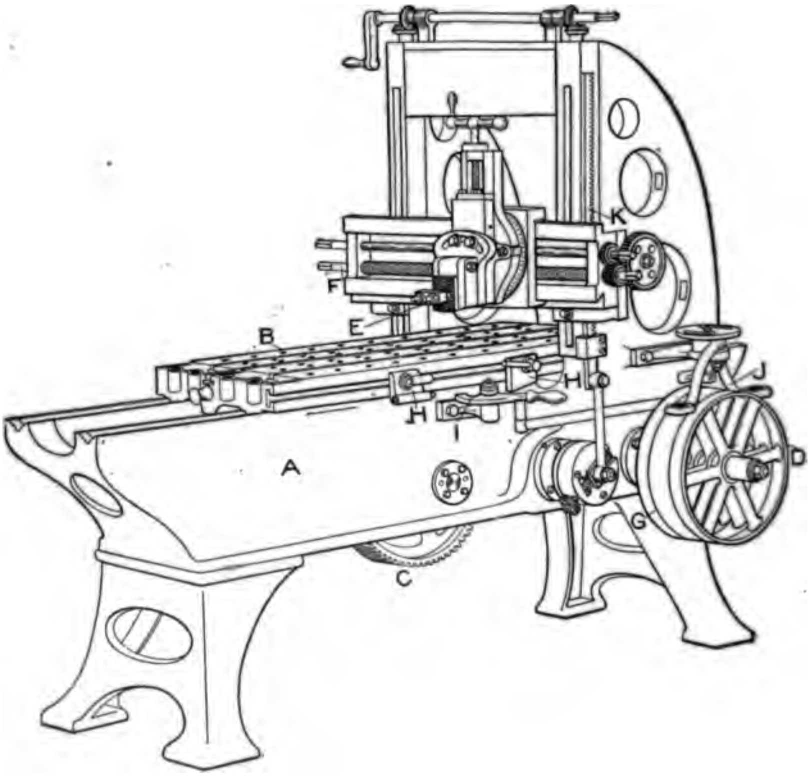

Fig. 173.

Planers are made in a great variety of sizes and styles. Very frequently there are three driving pulleys placed side by side on the same shaft, the central one of the three keyed to the

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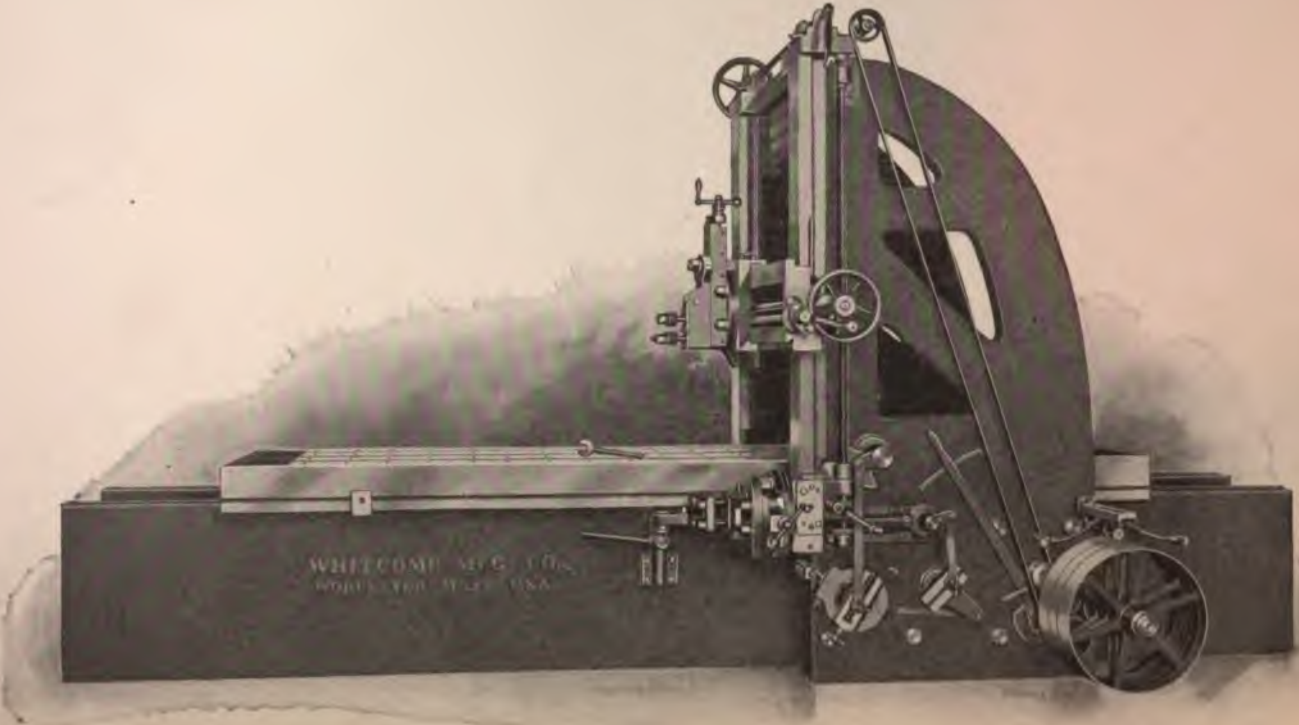

WHITCOMB MFG. CO.

36"x 36" x 10' PLANER.
Whitcomb Manufacturing Co.

shaft. The reversal of the motion of the platen is obtained by shifting one or the other of the belts onto the central pulley.

Planer Tools. The tools that are used upon planers do not differ essentially from those described for lathe work. The same rule applies regarding the holding of the tool. It should project as short a distance as possible beyond the point of support.

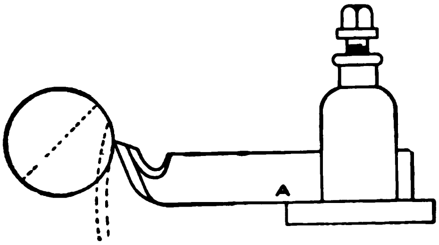


Fig. 174.

When there is an excessive projection, care should be taken that the tool is so set that it will not spring into the work. On the lathe this can be prevented by setting the point of the tool on a line with the center. In Fig. 174 the tool tends to spring and turn about the point A as a center. The dotted line at the point shows how this tends to throw it into the work. The same thing is shown in the planer tool in Fig. 175. This tendency can be overcome by forging the tool so that the cutting point is behind a perpendicular from the point of support, as shown by the dotted lines in Fig. 175. In the latter case the spring of the tool tends to take it out of the work.

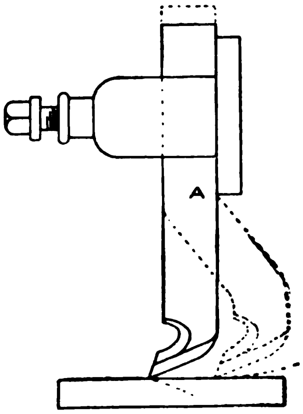


Fig. 175.

Holding the Work. The work is usually held on the planer by clamping it down with straps in a manner similar to that shown in Fig. 171. Where the whole upper surface is to be planed over, holes are sometimes drilled in the sides, into which the rounded ends of straps are set.

It is impossible to give more than general directions for clamping work on a planer. A great variety of blocking, clamps and bolts must be used; such attachments being suited to the work in hand, and requiring an outlay of money which seems to be out of proportion to the appearance of the collection. It should be sufficient to say that the work must be carefully set, strongly clamped and braced to prevent movement by the tool; the clamping should not distort the work. As all castings and forgings change their shape when the surface is removed, it is considered good practice to release the clamps before the finishing cut, in order that the piece may assume its final shape, and then reclamp it without distortion.

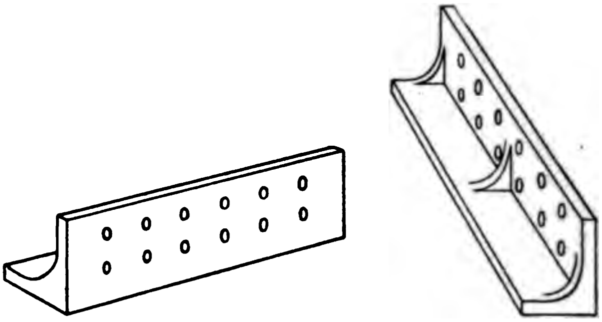


Fig. 176.

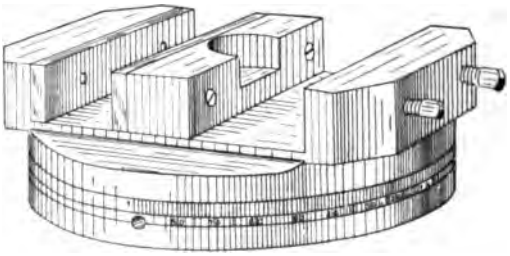
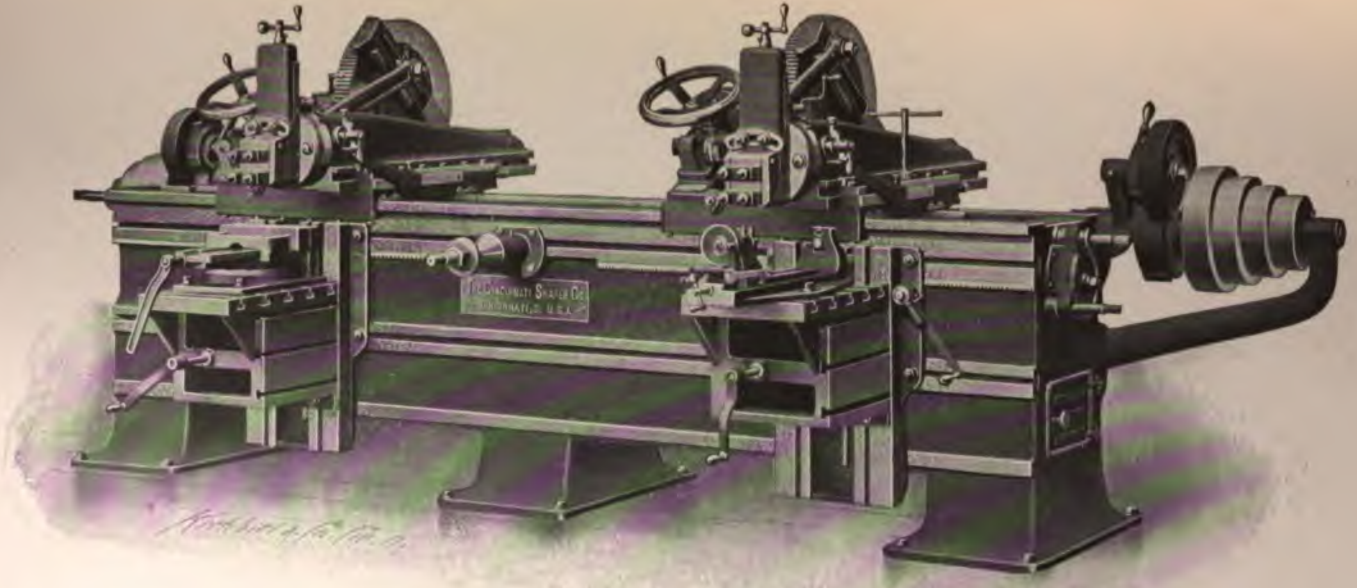


Fig. 177.

Angle irons or knees, as shown in Fig. 176, may be considered as an auxiliary table with a surface at right angles to the



TRAVERSE SHAPER.
The Cincinnati Shaper Company.

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main table. Many useful applications of these holding devices will suggest themselves.

Another method of holding work is by using a vise such as is shown in Fig. 177. The body is bolted to the platen and the work is held between the jaws.

Planer centers, as illustrated in Fig. 178, are very useful in machining parts where accurate circular spacing is desired, or where projecting lugs prevent turning in the lathe.

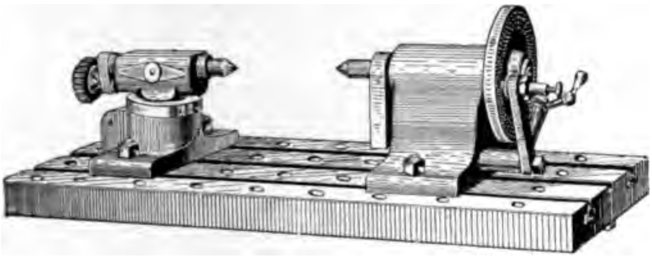


Fig. 178.

The Plate Planer. A special form of planer extensively used in boiler shops and shipyards is the plate planer, Fig. 179. It is used for planing the edges of long plates. The plate is securely fastened between the clamps A and the bed B. The tool is held in the carriage C, which is moved to and fro by the screw D. The screw is driven by the gear H, that meshes with a pinion keyed on the shaft to which the motor is geared. The reversal of motion is obtained by shifting the clutch K. The tappets M for moving the shifting gear are upon the shaft I. They are struck as the carriage approaches the end of its stroke. Unlike the ordinary machine shop planer, the plate planer has no quick return stroke, but has a tilting tool which allows stock to be removed when moving in either direction. Devices of this character have often been tried on regular metal planers, but seem to be satisfactory only when the whole face of the work can be covered at a single stroke of the tool.

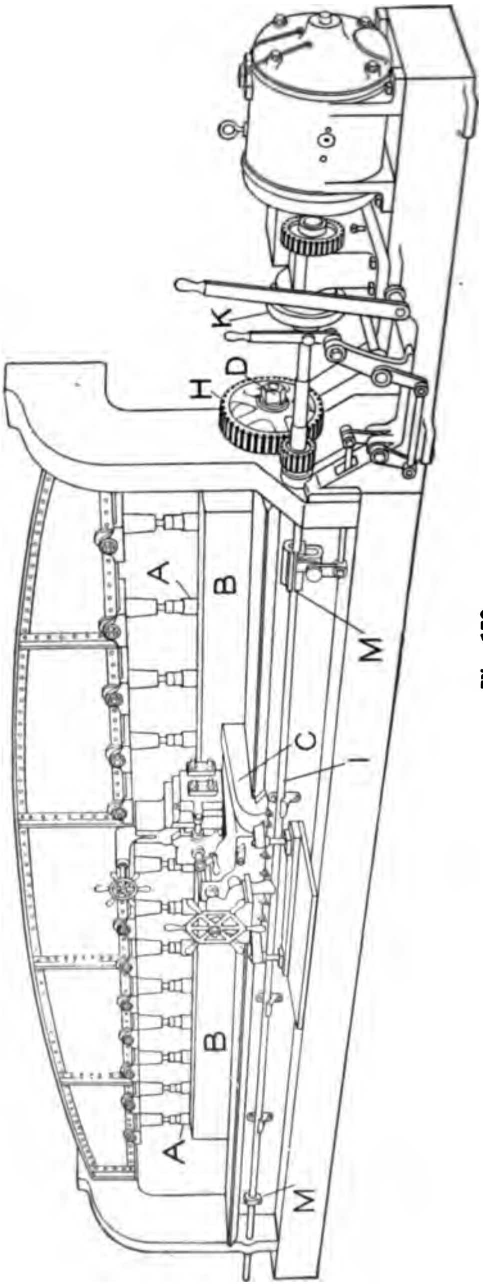


Fig. 178.

THE SHAPER.

For light work the shaper or shaping planer, Fig. 180, is extensively used. It possesses the advantage of rapidity of action. In this machine, as in the plate planer, the tool moves while the work is at rest. A suitable mechanism causes the ram A to move to and fro. When moving toward the left, the tool is cutting. As in the ordinary planer, the cutting speed is less than the return.

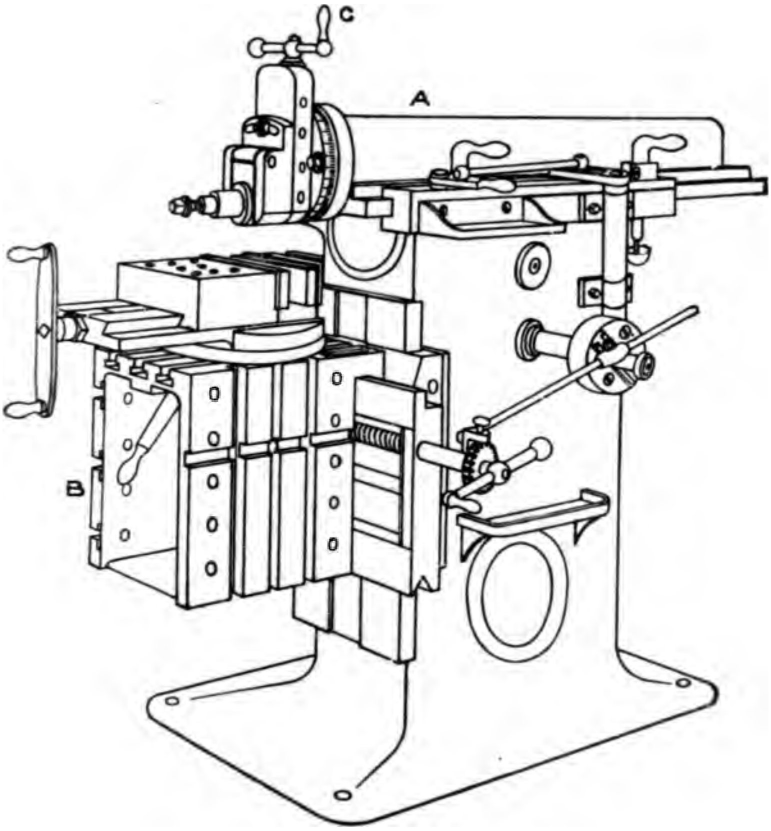


Fig. 180.

The work is held on the table B, which may be adjusted to any convenient height suited to the work to be done. The tool is also allowed a limited vertical adjustment in the slide by turning the handle C. This is the ordinary method of obtaining the vertical feed.

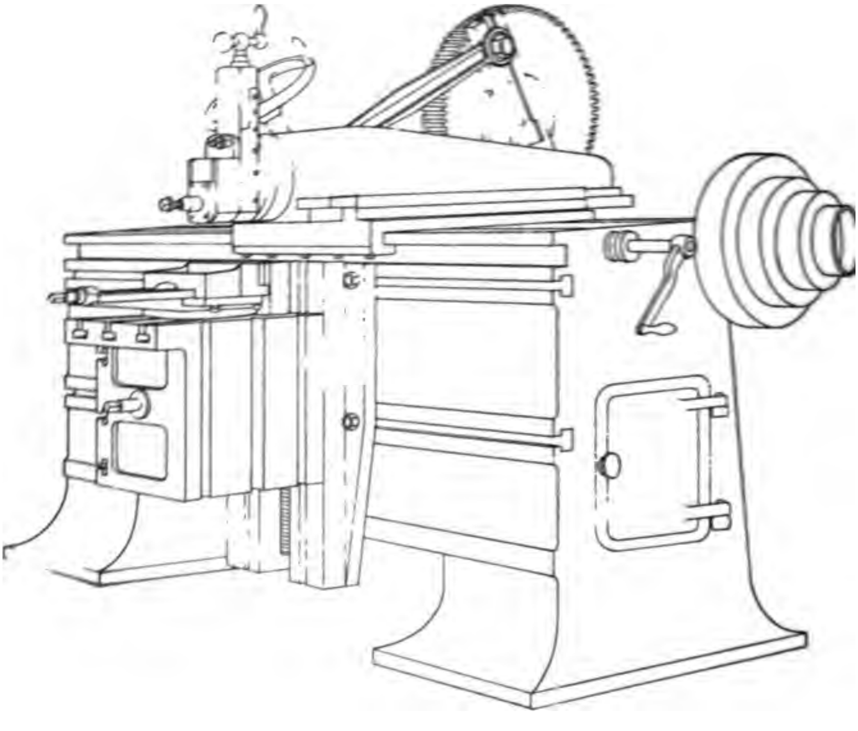


Fig. 181.

The horizontal feed is obtained by moving the table B sidewise. In some shapers it can also be moved vertically to feed to or from the tool; in others the horizontal feed is obtained by causing the tool with the reciprocating parts to move sidewise.

The style of machine shown at Fig. 180 is called the pillar shaper, but where the tool and ram move sidewise it is called the traverse shaper; see Fig. 181. The character of the work done on the shaper and the planer is identical, but as a rule, the shaper is used for the smaller and more delicate parts which could not be handled quickly on the planer. The shaper has the additional advantage of a change of speed which allows small pieces, especially of the softer metals, to be machined at a maximum rate.

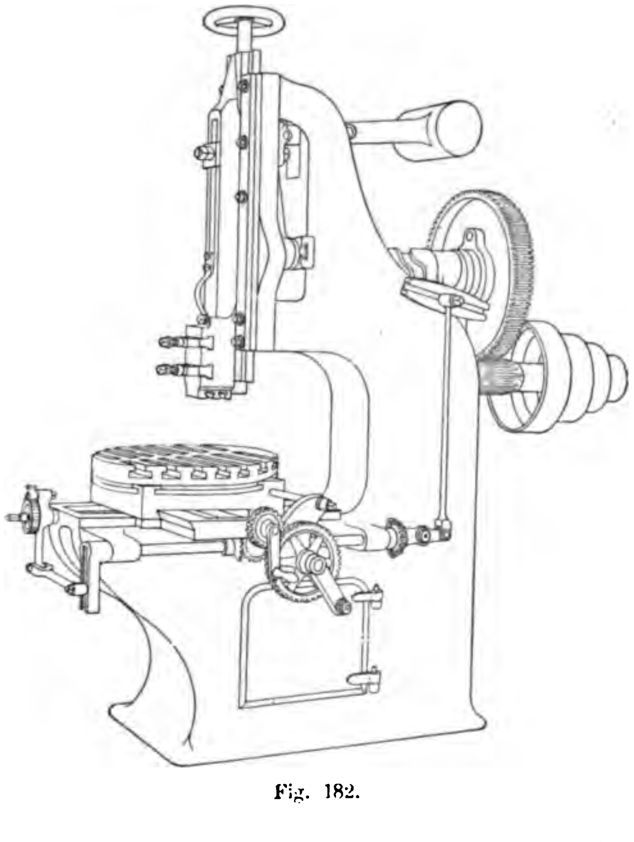


Fig. 182.

Slotter. Another machine tool which is not used as commonly as its many good qualities would seem to warrant is the slotter, Fig. 182. It is, in reality, a shaper with the tool moving vertically instead of horizontally. It is used for working on heavy pieces, and especially in places where an irregular contour is to be formed. The thrust on the tool is vertical, and it must be very stiff. The work done frequently partakes of the nature of the forming of the inside of the hole where the tool must project the whole length of the cut below the bottom of the head. Such a case is that of the slotting of locomotive frames. The best type of tool for such a class of work is a strong bar, as shown in Fig. 183. The bar is held in the head of the tool just as any tool would be. Near the lower end it carries the cutting tool, which may be fastened by a set-screw or wedge. Such a tool should always be used when it is possible. It has the advantage of being stiffer and less likely to spring than a forged tool.

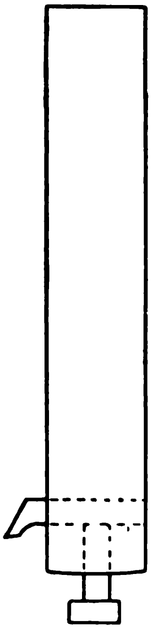


Fig. 183.

The tool used in a slotting machine differs from that used in the lathe or planer in that the direction of the cutting motion is different. Fig. 184 illustrates a slotting tool to be used for doing such work as the cutting of keyways in the hubs of pulleys. It will be seen that if the tool is moved in the direction of the arrow, the face B becomes the one against which the chip bears. It, therefore, corresponds to the top of the lathe tool. The sharper the slope given to the face B, the keener the edge, just as increasing the rake of the lathe tool increases its sharpness. The face A must also be cut away as indicated. This corresponds to the clearance of the lathe or planer tool. It is quite possible, at times, to give these tools a larger amount of rake. Such a form

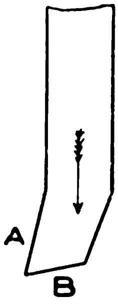


Fig. 184.

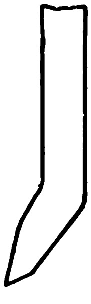
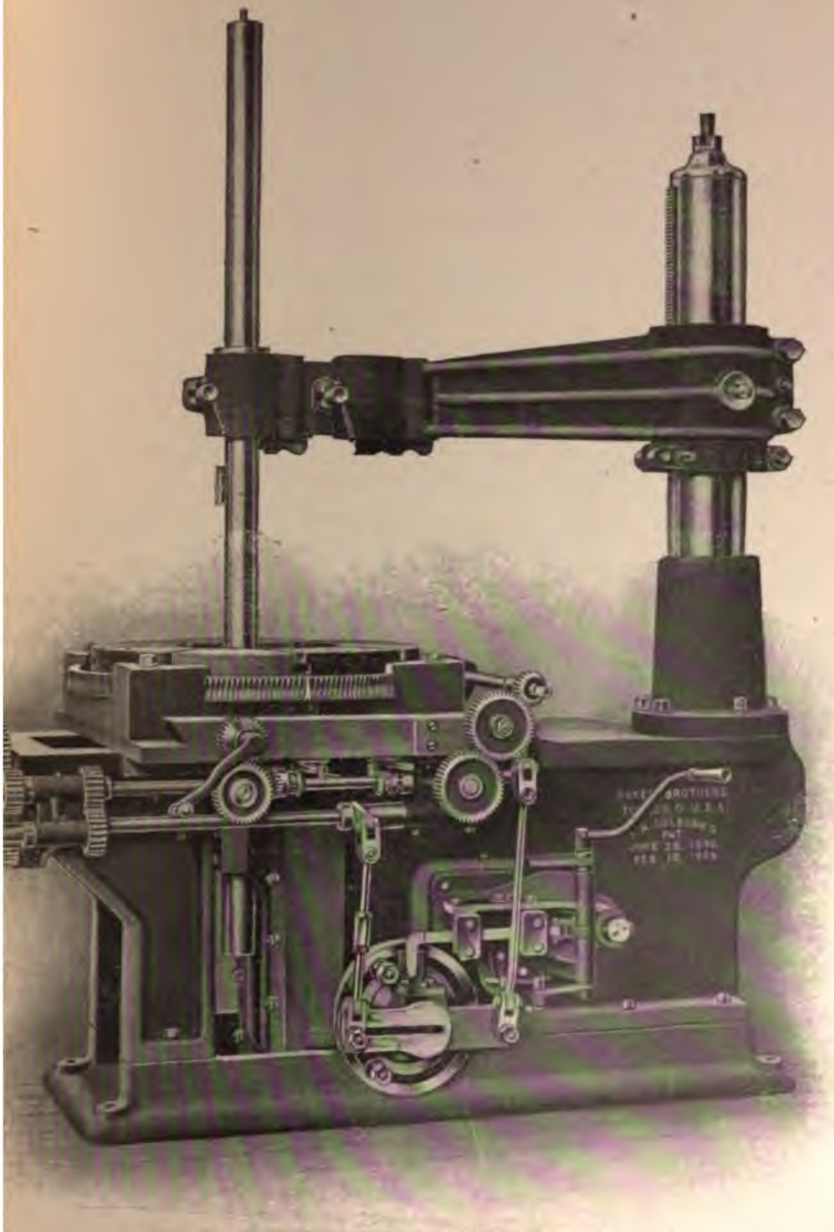


Fig. 185.



DRAW STROKE SLOTTER.
Baker Brothers.

is shown in Fig. 185. The shape of this tool is such that it is very strong in the direction of the thrust, besides having a keen cutting edge.

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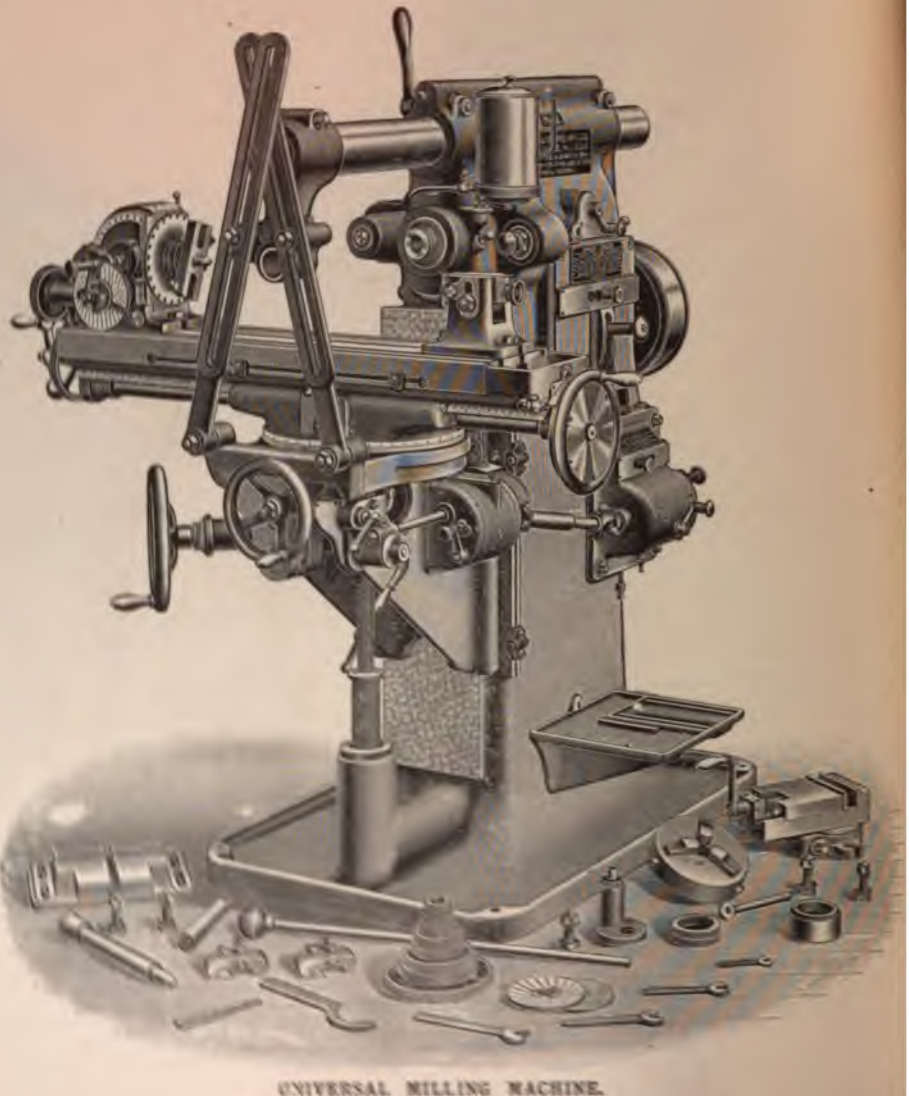


UNIVERSAL MILLING MACHINE.
Brown and Sharpe Mfg. Co.

MACHINE SHOP WORK.

PART III.

THE MILLING MACHINE.

The operation known as milling differs so radically from the removal of metal by methods previously described, that it merits much more careful and lengthy discussion than has been devoted to the other methods. Due, also, to its increasing importance and general use, it calls for a somewhat extended discussion. While milling is coming rapidly into favor as a means of doing work which has formerly been done on the shaper and planer, it does not follow that the shaper and planer are to be entirely abandoned. There has been a tendency during the past few years to belittle the planer and shaper in favor of the milling machine. This tendency is not warranted even by the rapid and economical method of milling. There is a large class of work which can be done accurately only by means of a single-pointed tool such as is used in the planer and shaper.

The fundamental difference between planing and milling lies in the character of the tool employed. The planer uses a fixed single-pointed tool with a reciprocating motion either of the tool or the work, while milling is performed by the use of a rotary tool with several cutting points, of which the circular saw is a familiar example. This rotary multiple cutter is the basis of all milling operations, and, as the saw may be taken as a good example of such a cutter, so the work done by the circular saw in cutting metal may be said to be an example of milling. The ordinary milling cutter is nothing more than a saw in which the contour of the cutting blades is made to suit the work in hand.

Circular saws for use upon metal have been, and still are, often mounted in a hand lathe, Fig. 186. The saw is held on an arbor between centers, and the work placed on a table rest, which takes the place of the T-rest used in ordinary hand turning. Here is an example of milling in its most primitive form; the work being fed to the saw by hand, with no guides or positive movements. It was an easy matter to provide guides on the table rest for the work, and the next real important step was to use an engine lathe in place of the hand lathe. Here the saw was mounted as before, the work clamped to the carriage by suitable fixtures and fed positively to the saw, both as to direction and amount.

It was but a step to make a saw wide enough to cover a considerable surface, or to have a thick saw with a suitably formed cutting edge. Several saws of different shapes and sizes can be mounted in a gang on an arbor and perform operations which it would be hard to duplicate on the shaper or planer. Even in the present age of special machines for milling, a great deal of work of this character is still performed in the engine lathe by the method indicated.

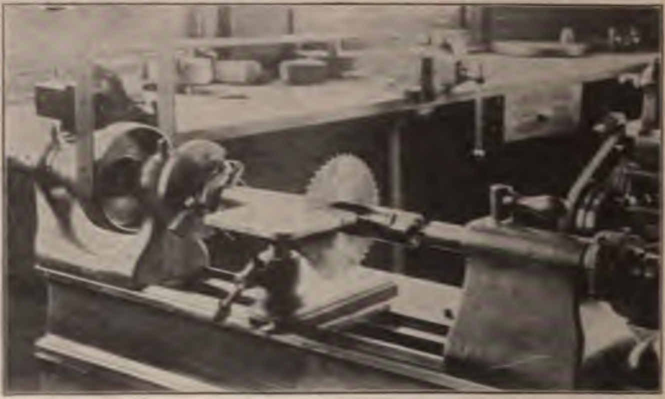


Fig. 186.

It is evident that one of the great advantages of milling is the certainty of exact duplication, a feature of prime importance in the manufacture of interchangeable work.

Of course, it was not to be expected that such an important operation as milling could be intrusted to a machine like the lathe, which was primarily intended for an entirely different, but equally important, class of work.

About the first machine built exclusively for milling was the so-called Lincoln miller, Fig. 187, which consists essentially of a bed carrying the equivalent of the head stock and tail stock of a lathe, with means for rotating the cutter arbor, which is carried directly by the head stock spindle, and steadied and supported by the tail stock. There is also provided a table upon which the work can be fastened either directly, or by means of a vise, and an automatic feed across the machine at right angles to, and below, the cutter arbor. This is simply the milling attachment in the lathe transferred to a machine designed to do nothing but milling.

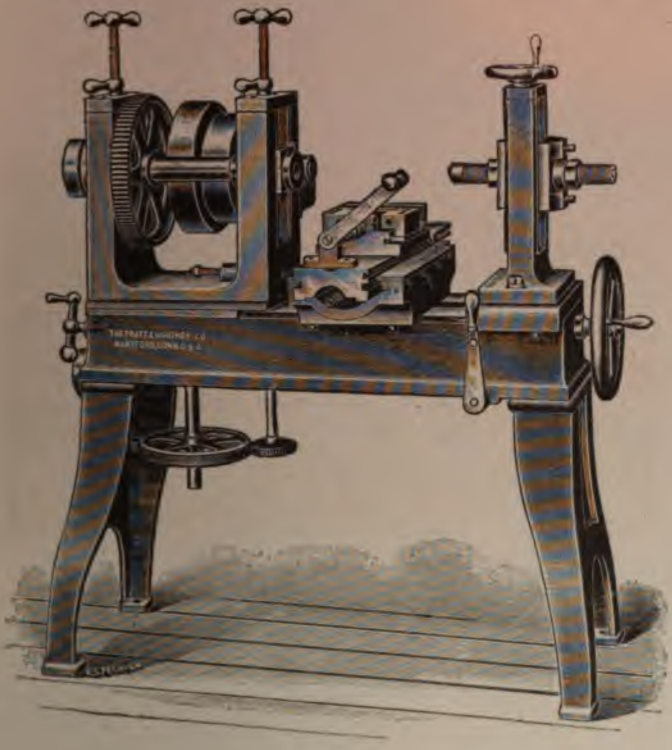


Fig. 187.

The elementary cutters designed to be used on this type of machine are of the form already described, viz.: of the saw type.

As the **types of cutters** used determines, in a large measure, the design of the machines themselves, it will be better at this point to take up a description of some of the different cutters, in order that the adaptation of the machine to the cutter may be clearly seen.

Screw slotting cutters, Fig. 188, and slitting saws, Fig. 189, are indentical with the saws which, we have already seen, were employed in the lathe. The true milling cutter, Fig. 190, has a face much wider in proportion to its diameter than the common saw. It is for the production of surfaces, rather than for a thin saw kerf for separating pieces of metal. These plain cutters are made in a large number of diameters and lengths, and are all designed for the generation of plane surfaces.

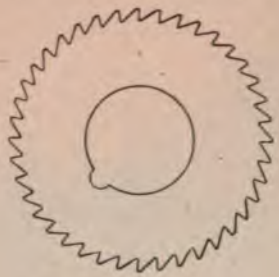


Fig. 188.

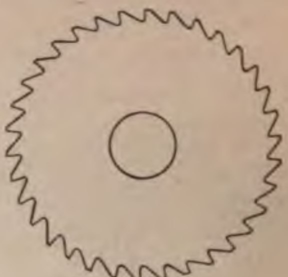


Fig. 189.

As we have seen in the case of reamers, heavy cuts can be taken more easily when the chip is broken up into small pieces, therefore in milling cutters designed for roughing, it is customary to nick the teeth, see Fig. 191, in such a way that the space left by one tooth may be taken out by the following tooth. This makes the cutting easier. A plain cutter of any considerable length will not make a smooth surface because of the varying pressure of the cutter, as one tooth after another leaves the work. To avoid this springing tendency, cutters are made with **spiral teeth,** Fig. 192,

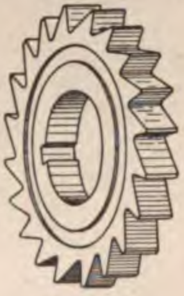


Fig. 190.

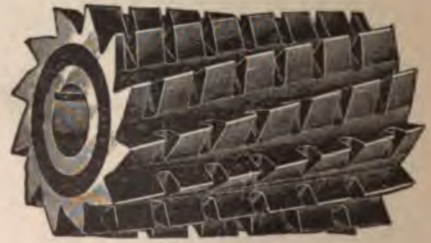


Fig. 191.

either right or left hand, so that there is practically a uniform distribution of pressure at all points during the cut.

When it is desired to mill the side of a piece, it is necessary that there should be teeth on the side of the cutter. Such cutters are usually made comparatively narrow and with teeth on both sides, as shown in Fig. 193. These **side milling cutters** are usually sold in pairs, as they can be mounted together and thus mill off both sides of a piece of work, similar to a bolt head, and are, therefore, called heading or straddle mills.

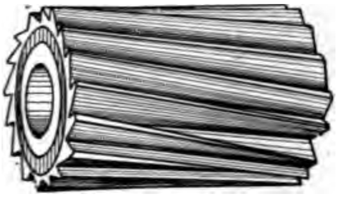


Fig. 192.

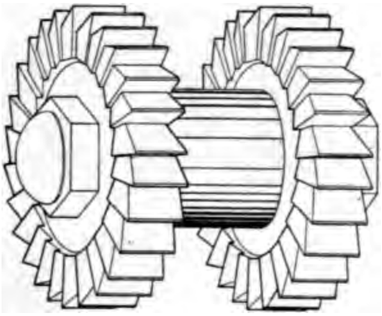


Fig. 193.

If two cutters of the same diameter are mounted together, it is difficult to mill a surface which will not show the point of separation of the cutters. This can be avoided by making the ends of the cutters, where they come together, of such a shape that they interlock one with the other. This feature of interlocking, see Fig. 194, is especially valuable when cutting slots which must be of a definite width. An ordinary cutter will wear away by use, or by grinding, and thus lose its correct size. The thickness of interlocking cutters can be maintained by means of very thin washers, and, due to the interlocking of the cutters, will not show that any space exists between them.

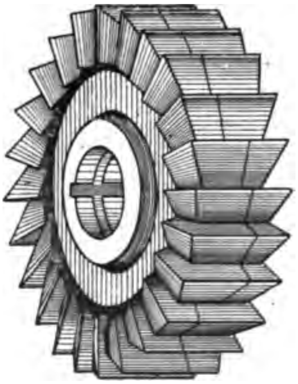


Fig. 194.

Cutters may be mounted in **gangs** of great variety and combination, a typical one being shown in Fig. 195. These cutters may be of any desired form, and can be made to produce a variety of shapes. The so-called angle cutters, Fig. 196, are employed in the manufacture of cutters, and, when making spiral cutters, must have an angle on both sides. The customary angle in such cases being 40° on one side and 12° on the other. The other common single angle cutters vary from 40° to 80°, either right or left hand. Double angle cutters can be had with either 45°, 60°, or 90°, included angle.

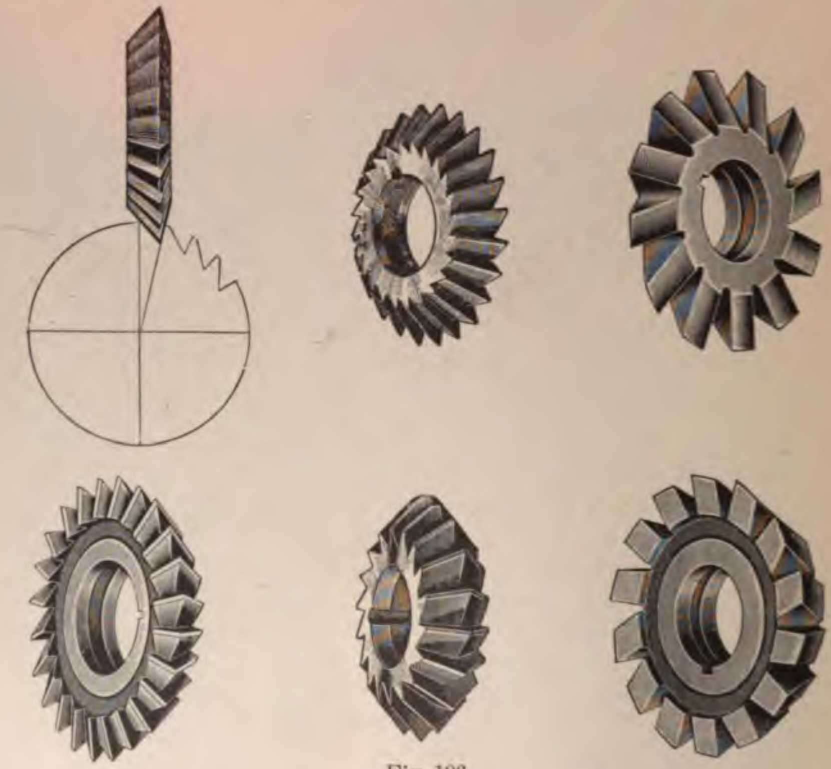
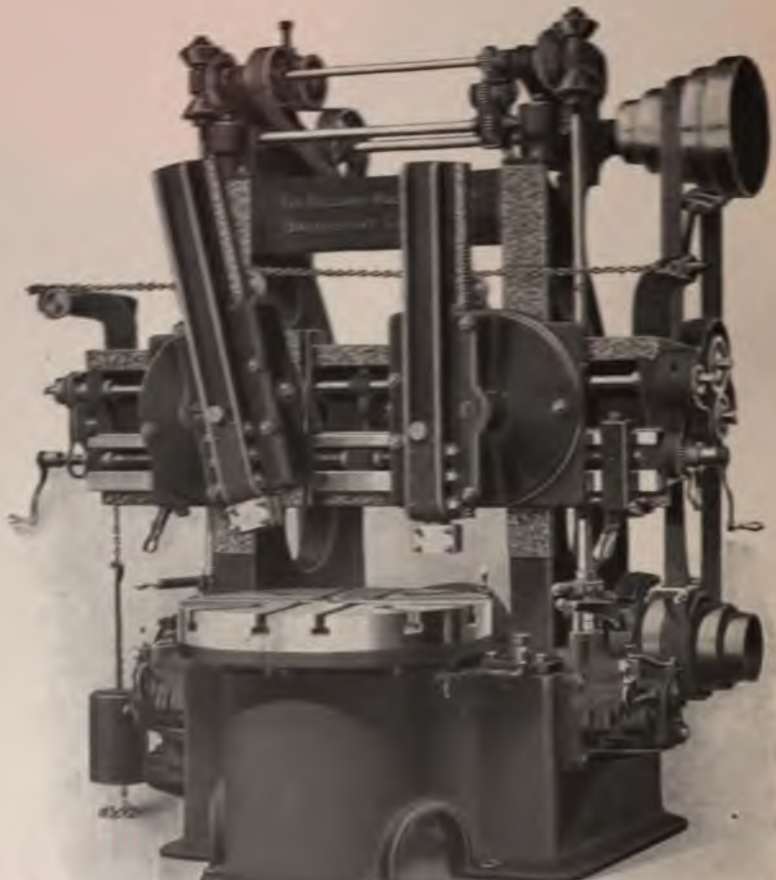


Fig. 196

We have considered up to the present time, only such cutters as are made from a single piece of steel. In large cutters, however, the cost of the steel becomes an important item, and there is danger of losing a large amount of labor through accidents in hardening. To make a cheap serviceable cutter of large size, it is customary to use a cast-iron body with inserted steel teeth. There



42-INCH RAPID PRODUCTION MILL.

The Bullard Machine Tool Co.

are several different methods of holding these teeth. Usually, when the inserted tooth is in the form of a blade, they are held by taper pins or screws, Fig. 197. These blades are renewable, the cast-iron body being used many times. A cheaper, permanent cutter can be made by casting the body around the teeth, thus making a very rigid support for the blades.

Another form of **inserted-tooth cutter** consists of round hardened steel pins driven into holes in a cast-iron body. This cutter is also permanent in form, Fig. 198, as broken teeth cannot be replaced, and, when the teeth are worn almost down to the body, the whole cutter is thrown away.

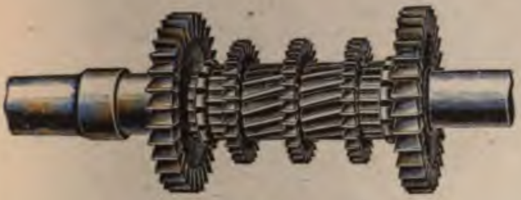


Fig. 195.

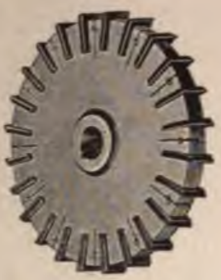


Fig. 197.

Brief mention has been made of cutters to generate irregular contours. These cutters are known as **formed cutters**, and, except in certain shapes, such as quarter and half rounds, are not carried in stock, but are made only to order. There is such a large variety of forms for which such cutters may be used, that it is impossible to give more than a typical example. The form shown, Fig. 199, consists in reality of several cutters, some of them of ordinary

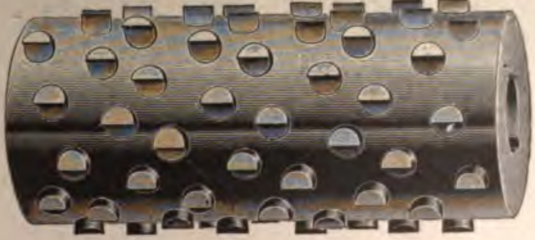
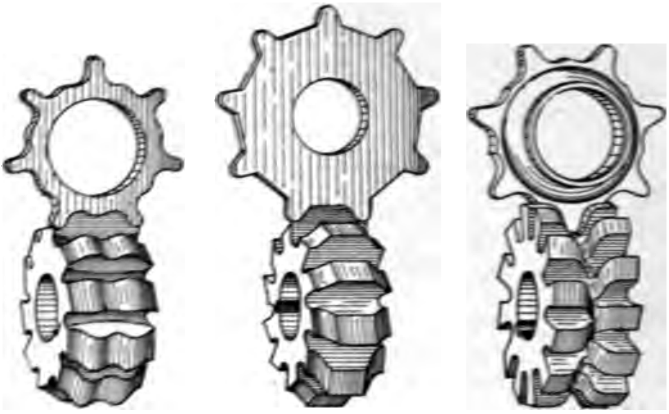
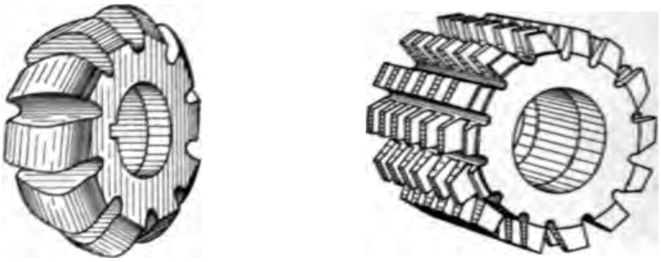


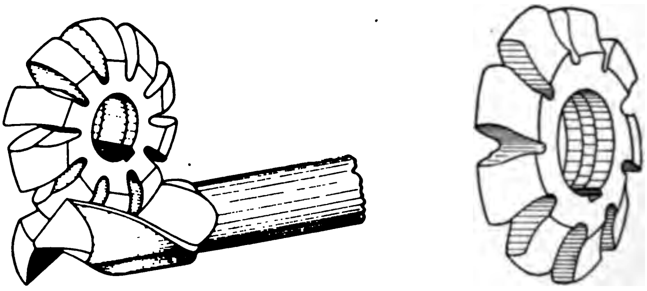
Fig. 198.



Sprocket Cutters.



Tap and Reamer Cutter. Worm Gear Hob.



Twist Drill Cutter. Gear Tooth Cutter.

Fig. 200.

shapes and sizes, with others of special forms, the whole making a gang cutter whose object is very apparent.

Among the standard shapes of formed cutters are some which are now carried in stock for producing certain tools which require cutters of definite yet peculiar form. Among these may be mentioned cutters for fluting taps, reamers, and twist drills, cutters for sprocket and gear teeth, and cutters, known as hobs, for the production of worm gears. See Fig. 200.

End Mills. All the cutters thus far mentioned are provided with central holes, and are intended to be mounted on an arbor which is carried by the spindle and supported in some suitable manner at the outboard end. There is an entirely different class of cutters, however, which are supported by the spindle only, and are provided with teeth on the end of the cutter. These are known as end mills. They are made in a great variety of shapes and sizes, the ordinary end mill, Fig. 301, being cylindrical, with either a right or left-hand spiral.

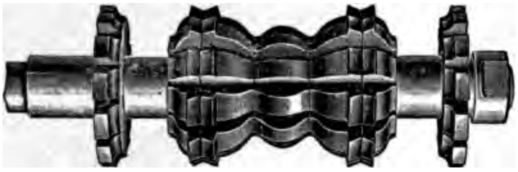


Fig. 199.

A special form of end mill for making T-slots is called the T-slot cutter, and is, in reality, a small side milling cutter carried by a small central stud, see Fig. 202. Dovetail cutters, and cutters of various angles for making ratchets, are merely variations of the end mill.

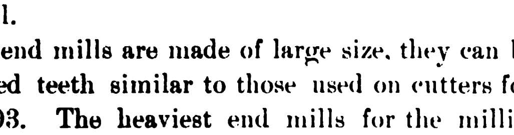
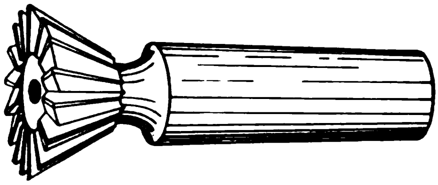


Fig. 201.

When end mills are made of large size, they can be furnished with inserted teeth similar to those used on cutters for the arbor. See Fig. 203. The heaviest end mills for the milling machine are sometimes made as large as fifteen to twenty inches in diameter, the cast-iron body being screwed directly on the nose of the spindle, making a very powerful and fast-cutting tool.

The plain milling cutter is mounted on an arbor in a way very similar to that in which its prototype, the circular saw, was mounted. For use in the lathe, this is usually centered at both ends and driven by a dog. When used in a regular milling machine, the arbor, Fig. 204, is fitted with a heavy taper shank



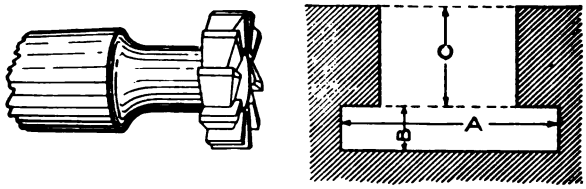


Fig. 202.

with a tongue at the end for driving, and washers of varying thickness, so that cutters of different widths may be used on the arbor, and, to suit the position of the work, in different positions on the same arbor. The washers and the cutter must have absolutely parallel faces. Otherwise, when the nut at the end of the arbor is tightened, there will be springing of the arbor due to the irregularity in thickness. The outboard end of the arbor is provided with a center or straight pin to be steadied by the over-

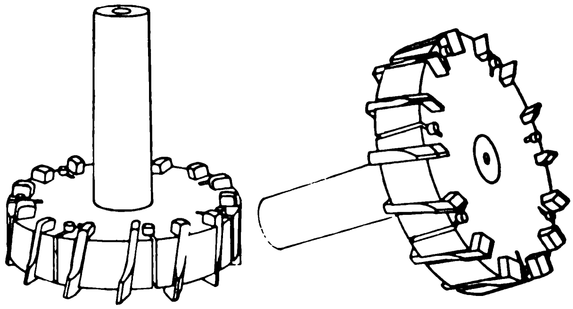


Fig. 203.

hanging arm, and the nut on the arbor should not be tightened until this arm is in position, as there is danger of springing the arbor by the leverage of the wrench.

Where the cutter teeth are formed integral with, or fastened to, the taper shank, as in the case of end mills, the shank, if it be of a proper size, is forced directly into the taper hole in the spindle. In many cases, however, the taper shank of the cutter is much too small to fit the spindle hole, and taper collets, Fig. 205, are used to bush down the spindle hole to the proper size. Of course, it is necessary that the axes of the outer and inner tapers should coincide, otherwise the cutter will not run true. In some cases it is necessary to use two collets, one within the other, before introducing the cutter shank.

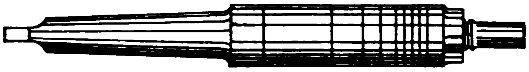


Fig. 204.

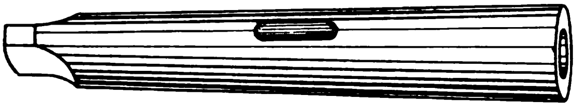


Fig. 205.

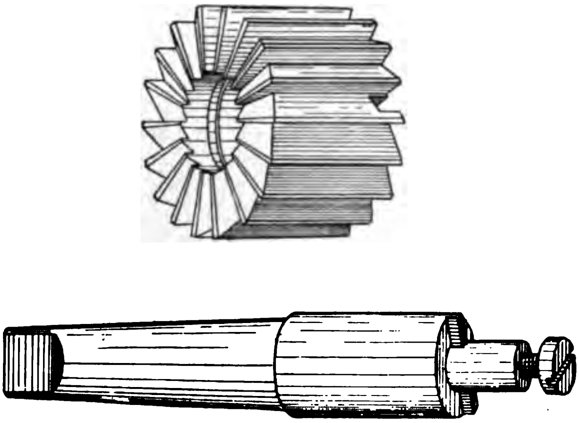


Fig. 206.

When **shell end mills,** Fig. 206, are used, a special form of taper shank is employed which can take several different sizes of cutters. The construction is so obvious from the illustration that explanation is unnecessary.

End mills, held on taper shanks, rely on the friction of the taper for holding in position, although being driven by a tongue at the end of the shank. Therefore, cutters of this description should not have a spiral in a direction which would tend to pull the cutter out. This is not a serious objection when using the cylindrical portion of the cutter, but, when using the end of the cutter, it means that the teeth can have no rake and must scrape, rather than cut the work. In order to use a leading spiral on the cutter, the shank must be held positively in the spindle. This usually is accomplished by inserting in a threaded hole at the rear end of the shank, a rod which extends through the hollow spindle and brings up against a collar on the outside. This can be set up solidly, and all danger of loosening up of the cutter shank will be avoided.

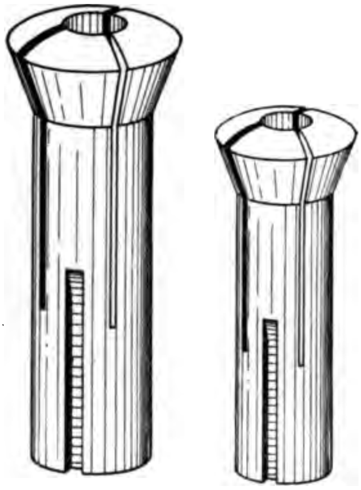


Fig. 207.

When the cutter is small, as compared with the diameter of the spindle taper, a screw collet may be used, as the friction of the collet will be greater than the tendency of the leading spiral to move the cutter from the spindle. Again, these screw collets are commonly made of machine steel, while the end mills are made from tool steel. The short, steep taper and threaded end are shorter than the long taper shank, and therefore make a cheaper cutter.

One of the best means for holding small end mills is by the use of spring collets, Fig. 207, which can firmly grasp the straight shank of the cutter. When cutters are to be changed frequently, this is a particularly satisfactory method, although it will not answer for roughing cuts with cutters of large diameter.

An ordinary drill chuck can be held in the spindle by means of a taper shank, and furnish a means of holding straight-shank drills and other small straight-shank tools.

A very convenient method of holding certain tools consists in fitting a three-jawed universal lathe chuck to the threaded nose of the spindle, thus enabling straight-shank tools of large size to be held firmly and accurately. Cutters of any kind are rarely held in chucks on the milling machine, but a large number of other small tools can be thus fastened to very great advantage.

In taking up the subject of machines devoted especially to milling, it is well to consider that the transition from milling in the lathe to the special milling machine, is bridged by an attachment to the lathe by which the functions of the milling machine were well served. This is especially noticeable in milling attachments attached to bench lathes, Fig. 208, said attachment being mounted on a foot connected with the end of the bed, and the head stock turned around on the bed to serve as a spindle for the milling attachment. This temporary arrangement, which is still used as a combination in some cases, led to the introduction of the **bench miller**, Fig. 209, which was naturally intended for small work only, and therefore is not provided with automatic feeds, hand feeding by means of levers being used.

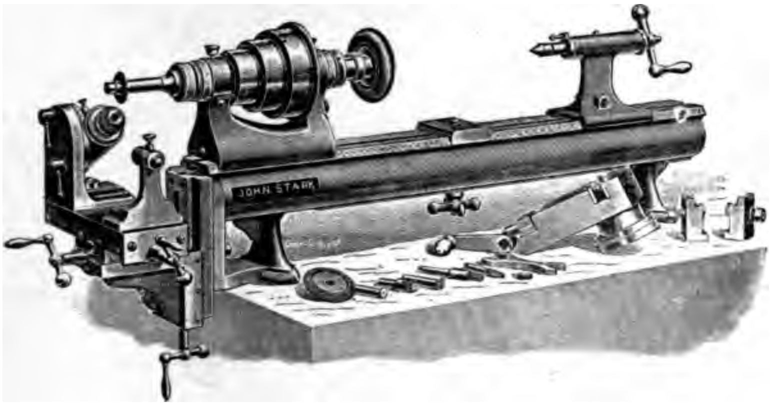


Fig. 208.

As this bench milling machine comprises all the essential elements of the more elaborate machines, it will be well to call attention to the principal parts of the machine and their functions.

The horizontal milling machine consists of a frame or box structure carrying a horrizontal spindle in the upper portion, together with brackets or an overhanging arm to steady the spindle. The front of the machine is carefully scraped at right angles to the spindle, and there is mounted thereon a knee, its upper surface being parallel to the spindle in the horizontal plane and capable of movement in a vertical direction. This knee carries what is known as the saddle, the upper portion of which is also parallel to the spindle. The movement of the saddle is towards and from the frame of the machine, and therefore parallel to the spindle. The saddle, in turn, carries the table to which the work is attached by means which will be described. The upper surface of the table is parallel to the spindle, and the table movement is at right angles to the spindle in the horizontal plane.

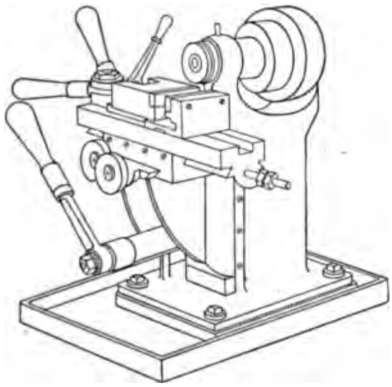


Fig. 209

The combination of these three motions, at right angles to the spindle in the vertical plane, parallel to the spindle in the horizontal plane, and at right-angles to the spindle in the horizontal plane, give to the milling machine what is known as its range. It allows any portion of the table to be brought under the cutter at any distance covered by the vertical feed.

Among the principal advantages of the milling machine, are the wide range of working capacity and the accuracy with which the table can be placed with relation to the cutter. This accuracy is obtained by means of graduated dials on the feed screws, which are read directly to .001 inch, and, by estimation, to .00025 inch. For many years the milling machine was the only tool which supplied these **micrometer graduations,** but they are now being applied to nearly every class of machine tool in which accurate adjustment is necessary. A very common method of graduation is by the use of a screw with a pitch of $\frac{1}{5}$ inch and 200 graduations on its dial. In some cases, a screw with a pitch of $\frac{1}{4}$ inch is used with 250 graduations, but it is always safe to assume that the single graduation on a milling machine means a movement of .001 inch.

Lost motion or backlash between the screw and its nut in any of these adjustments is the cause of frequent error and should never

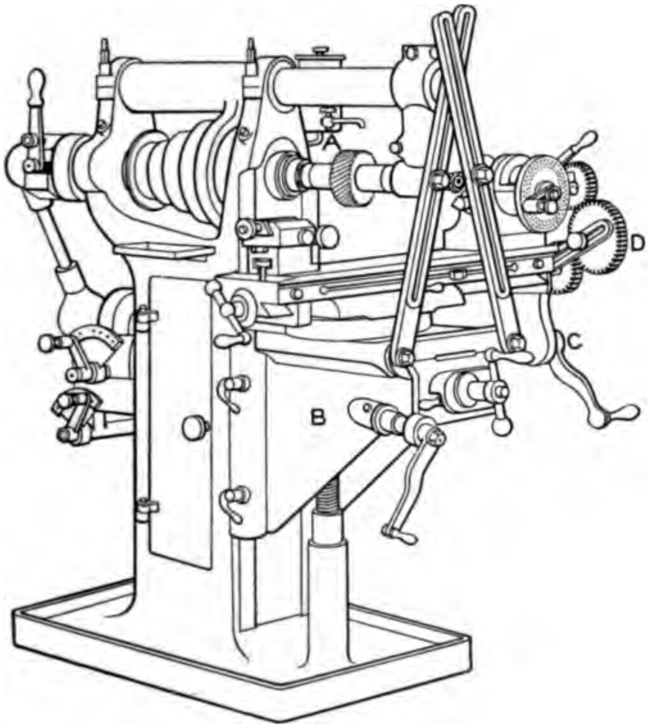


Fig. 210.

be neglected. Even in a machine in excellent condition, when the motion of the screw is reversed, it will turn through an angle giving the equivalent of about .005 inch movement of the part being fed along, but with no actual movement of the part. As an example, if, in moving the table from the column, the operator carries it .003 inch too far, it will not suffice to simply turn the dial back three graduations. The table should be brought back several hundredths of an inch, and then advanced to within .003 inch of its former position. In order to facilitate the quick and accurate reading of these dials, they are arranged so that they can be readily set to zero whenever desired.

The movements above described for the adjustment of the work are those necessary for what is termed a plain milling machine. In order to have a **universal milling machine**, Fig. 210, it is necessary that the table be so arranged that it can be swung upon the saddle in the horizontal plane, so that its feeding movement is not at right angles to the axis of the spindle. Universal milling machines usually have a total angular movement of 90°, 45° on either side of the normal position.

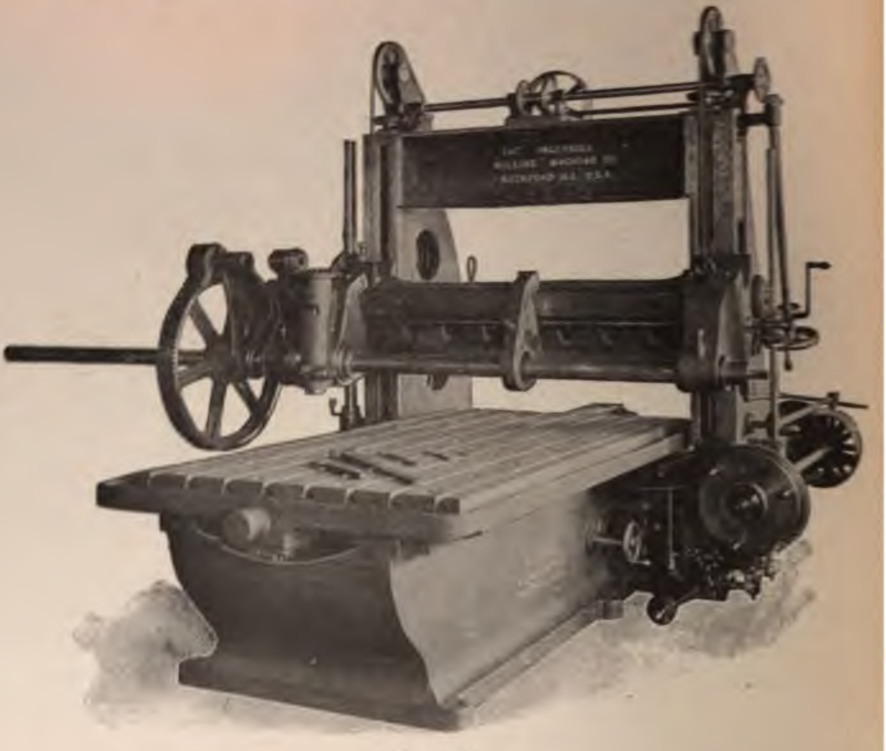


Fig. 211.

While the milling machine developed from the lathe through the Lincoln miller to the standard horizontal universal machine, its development, for work on which heavy cuts are necessary, took an opposite course.

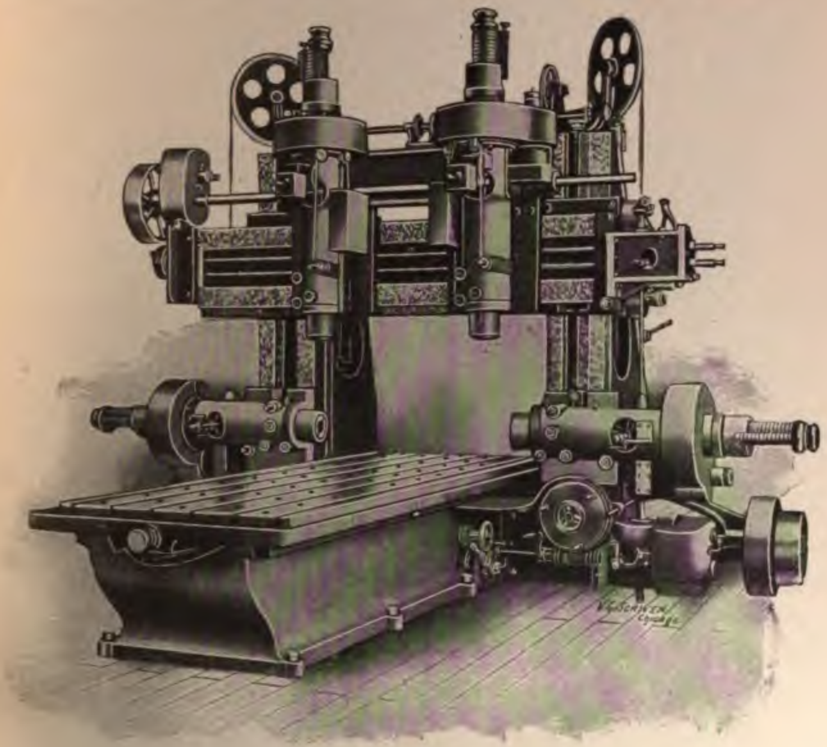


Fig. 212.

The slabbing miller, Fig. 211, is of the planer type, the cross rail carrying a rigidly supported cutter, while the table has the comparatively slow feed required for milling. This type of machine is especially valuable where broad surfaces are to be machined on pieces of work which are of such shape that they can be readily and uniformly supported to withstand the cut.

In order to produce true work by heavy milling, it is not only necessary that the work shall be supported as already outlined, but also, that the cut be nearly uniform in depth and width. If the section of the cut varies greatly, or, even with uniform cut, if the work is irregularly supported, the metal will spring under the influence of the cutter and it will be found that the work is not true. Therefore, work of a character that is liable to be distorted by the process of milling, may easily be performed to better advantage by the process of planing.

As the planer is sometimes furnished with more than one head, so these heavy milling machines are often furnished with more than one spindle. Two vertical heads on the rail and a facing head on each upright, Fig. 212, makes a machine capable of removing a large amount of metal, if the work is of such a character as to stand up under the cut.

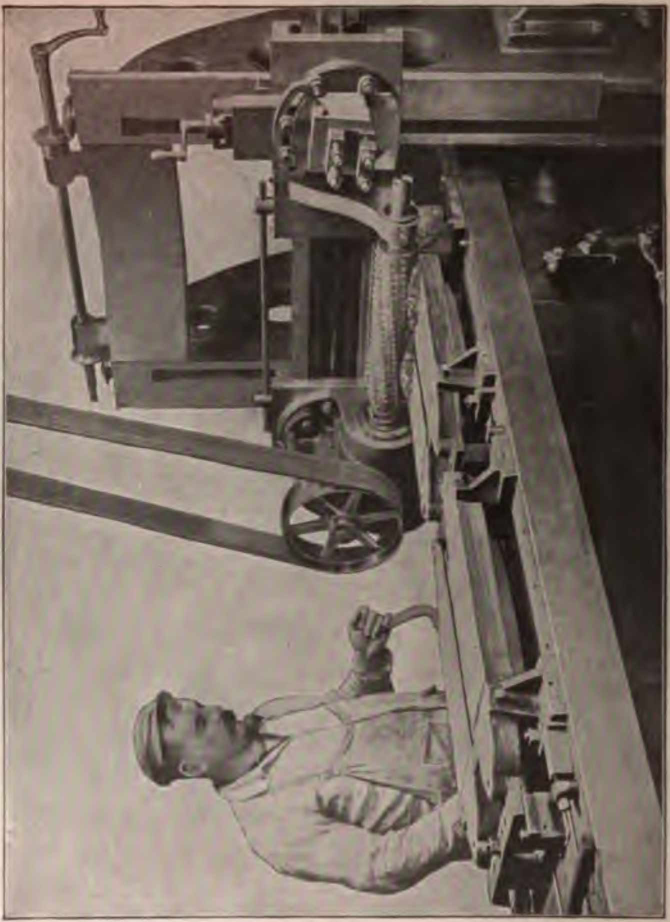


Fig. 213.

It is often desirable, from the point of view of economy of time, to combine the operations of milling and planing, and, with this end in view, milling attachments are made for the planer, Fig. 213, and attached to the cross rail. The changes required from the planer drive, are an extra belt to rotate the cutter and a special countershaft to slow down the movement of the table. This attachment can carry a slabbing, gang, or formed cutter on an arbor for horizontal milling, or it can carry end mills, Fig. 214, by turning the head through 90°, thus bringing the spindle to a vertical position. This last arrangement of the spindle is of great utility, as it allows cutters to reach down into places which would be inaccessible by any other means.

The advantages of the **vertical milling spindle** are so evident, that nearly all makers of horizontal machines furnish what is called a vertical head, Fig. 215. This vertical head is very rigidly supported on the column, and by means of the overhanging arm, so that cuts can be taken of as great depth as with the horizontal spindle. The vertical spindle can also be turned in the vertical plane, so that an end mill can be used at any angle with the table.

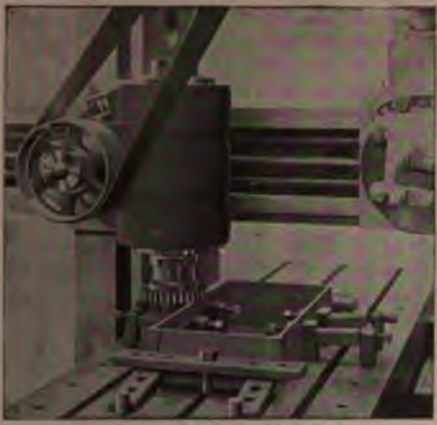


Fig. 214.

There are several machines made in which the vertical spindle alone is employed, Fig. 216, there being no provision for a horizontal spindle.

Such machines are provided with the feed motions of the horizontal type, and also with a rotating table by which circular work can be done. A large amount of work formerly done in lathes is now being done in vertical spindle machines, as well as many pieces formerly machined on planers and shapers.

The duplex milling machine, Fig. 217, has both the horizontal and vertical spindles combined in one, which allows the spindle to be placed at any angle from horizontal to vertical, and combines all the good points of both machines. The head of the duplex miller can be moved out over the table in such a way as to greatly increase the range of the machine, and this head is also provided with a drilling attachment whereby holes may be drilled at any angle. Attention is called to the rope drive on this machine by means of a twisted rawhide belt or rope. This makes a very smooth and quiet drive.

In order to accommodate different sizes of cutters, maintain a uniform cutting speed, and also to allow for difference in hardness of the material being worked, it is necessary that the milling machine should be supplied with several speeds. In the ordinary miller we usually have a four-step cone with back gears, which gives eight speeds with a single overhead belt. The countershafts for these machines are of the friction type, and are supplied with two driving pulleys in order that the machine may be driven in either direction. But, if the reverse motion is not desired, there can be two pulleys driving in the same direction, but at different speeds, giving a total, including the back gears, of sixteen speeds for each machine. The speed used on any particular work depends, as before stated, on the diameter of the cutter and the character of the work. Thus, with carbon steel cutters, the cutting speed will be 30 to 60 feet per minute. With high-speed steel cutters, nearly double these speeds may be maintained, if the drive of the machine is strong enough to pull the cut.

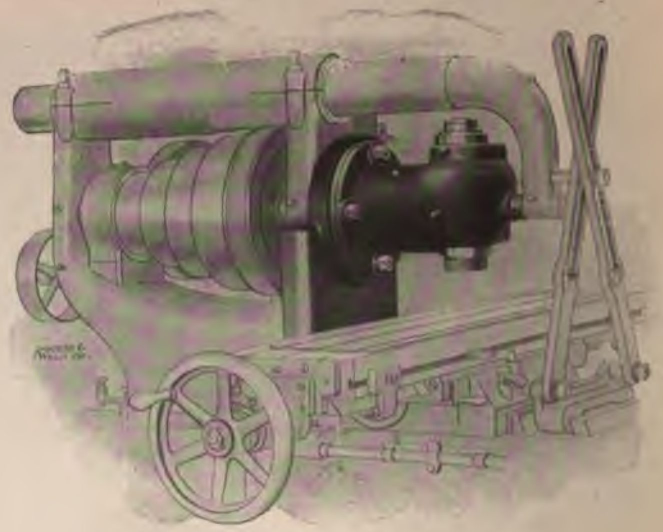


Fig. 215.

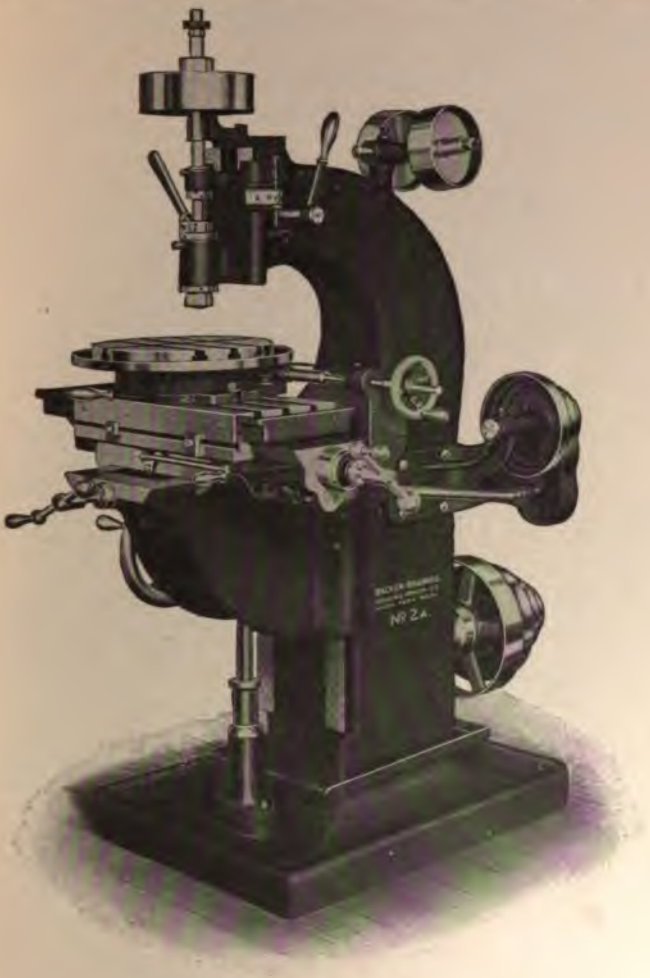


Fig. 216.

When using very small cutters, the machine itself will not give a speed which is high enough to suit the diameter of the cutter. For such work, a high-speed attachment, Fig. 218, is furnished, by which the small, light cutters may be driven at a suitable rate.

Of equal importance with the correct speed for the cutter, is the maximum feed or table speed, which is reckoned in inches per minute. A more logical method of designating the feeds, and one which has been adopted by several makers, is to give the advance of the table in thousandths of an inch for every turn of the spindle.

Based upon the use of the ordinary carbon steel cutters, The Brown & Sharpe Co. have prepared the following statements regarding the speed of mills: "It is impossible to give definite rules for the speed and feed of mills. The judgment of the foreman or man in charge of the machine should determine what is best in each instance.

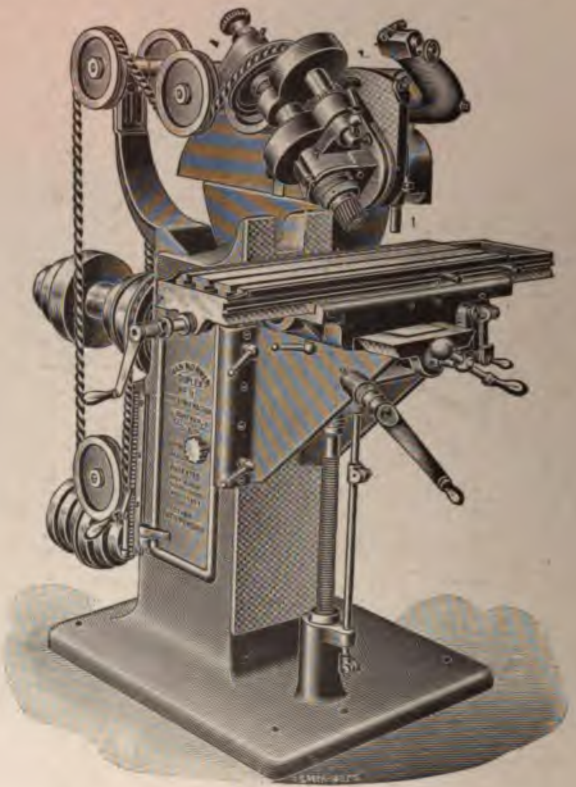
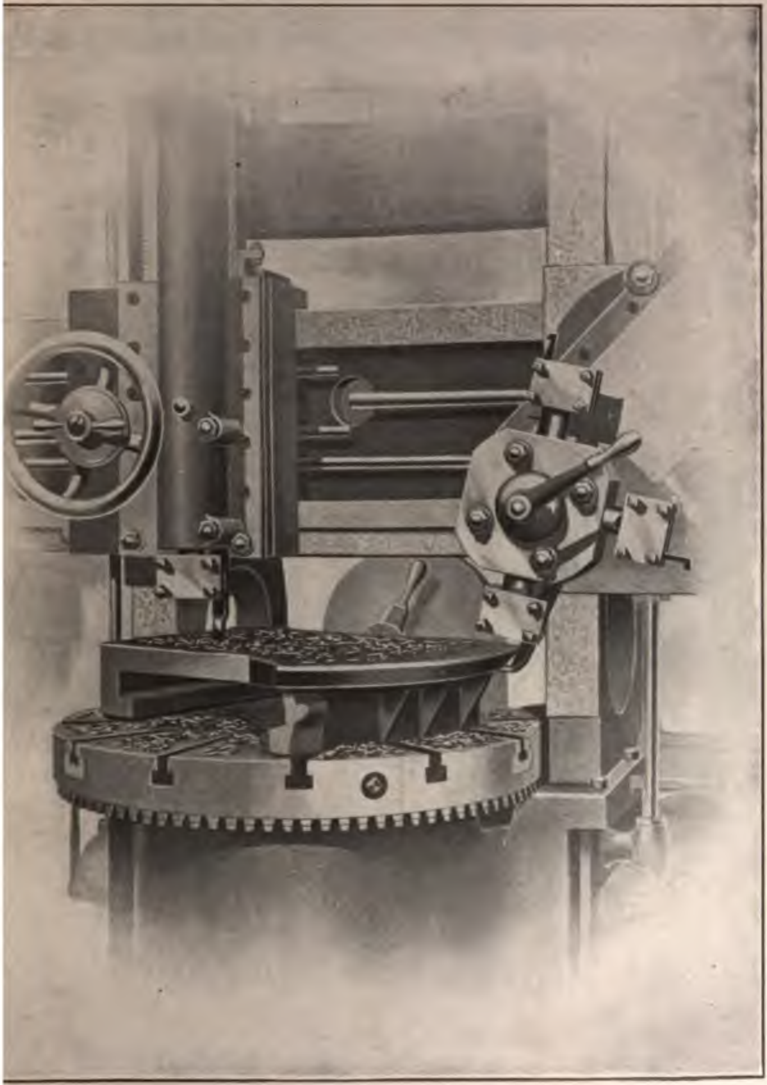


Fig. 217.

"As usually the highest possible speed and feed are desirable, it pays to increase them both until it is seen that something will break or burn, and then reduce to a speed and feed of safety. Sometimes the speed must be reduced, and yet the feed need not be changed.



BORING AND TURNING MILL.

Turning Bevel with Swivel Head.

Bullard Machine Tool Co.

"The average speed on wrought iron and annealed steel is, perhaps, 40 feet per minute, which gives about sixty turns per minute with mills 2½" in diameter. The feed of the work for this surface speed of the mill can be about 1½" per minute, and the depth of the cut about 1/16". In cast iron, a mill can have a surface speed of about 50 feet a minute, while the feed is 1½" per minute and the cut 3/16" deep. In tough brass, the speed may be 80 feet, the feed the same as in cast iron, and the chip 3/32".

"As small mills cut faster than large ones, an end mill, for example, ½" in diameter, can be run about 400 revolutions per minute with a feed of 4"."

Addy, an English authority, gives as a safe speed for cutters of 6" diameter and upwards:

Steel, 36 ft. per minute with a feed of ½" per minute.
Wrought Iron, 48 ft. per minute with a feed of 1" per minute.
Cast Iron, 60 ft. per minute with a feed of 1⅔" per minute.
Brass, 120 feet per minute with a feed of 2⅔" per minute.

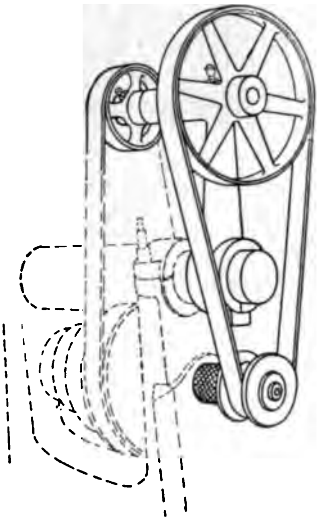


Fig. 218.

He also gives a simple rule for obtaining the speed: The number of revolutions which the cutter should make when working on cast iron = 240 divided by the diameter in inches.

The following table has been prepared by Messrs. Brown and Sharpe to give the speed, feed, and depth of cut that can be obtained with a machine similar to that illustrated in Fig. 210.

SURFACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
3	42	34	1/16	1	6 5/8	8 7/8
	42	34	1/8	1	4 1/8	6 1/2
	42	34	1/16	2	6 5/8	8 7/8
	42	34	1/2	2	2 1/2	4 1/8
	42	34	1/16	3	6 5/8	8 7/8
	42	34	7/16	3	1 3/8	2 3/16
3 1/2	42	40	5/32	8	4 1/8	6 1/4
	42	40	1/8	3 1/2	2 1/2	3 1/2
4 1/2	42	50	1	2	4 1/8	6 1/2
	42	50	1	4	3 1/2	4 1/8
	42	50	1	6	2	2 1/4
	42	50	1/8	6	4 1/8	6 1/2
	42	50	11/32	12	1 3/8	2

SURFACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
3	38	30	1/16	1	6	8
	38	30	1/2	1	1 1/8	1 7/8
	38	30	1/16	2	2 3/8	3 1/2
	38	30	1/2	2	3/4	1 1/8
	38	30	1/16	3	1 1/8	1 7/8
	38	30	3/8	3	3/4	1 1/8
3 1/2	38	35	1/16	8	1 7/8	3
	38	35	1/8	8	3/4	1 1/8
4 1/2	25	30	1/16	3	4	5
	25	30	1/16	5	2 1/2	4 1/2
	25	30	3/8	5		1/2
	25	30	1/16	10	1 3/4	2 1/2
	25	30	3/16	10	1/2	7/8

END OR FACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
½	382	50	1/16	½	23	35
	382	50	⅛	½	7	11
1	191	50	1/16	1	30	40
	191	50	½	1	3	5½
1¾	109	50	⅛	1¾	17	23
	109	50	¾	1¾	3⅝	4⅛
5	42	55	¼	5	2⅝	4⅛
16	10	45	¼	16	⅞	1

FACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
½	267	35	1/16	½		
	267	35	¼	½		
1	152	40	1/16	1	3	4¾
	152	40	½	1		
1¾	87	40	1/16	1¾	2¾	4½
	87	40	¾	1¾		1¾

The milling machine, and in fact all the machines of the shop, can do efficient work only when they are well cared for. An important element is that they should be kept clean and well oiled.

Great care should be exercised that chips do not get into the holes in the spindles or between the arbor collars.

When at work, the milling cutter is kept flooded with oil or a solution of sal soda as already specified for lathe work.

Oil is used in milling to obtain smoother work, to make the mills last longer, and, where the nature of the work requires, to wash the chips from the work or from the teeth of the cutters. It is generally used in milling a large number of pieces of steel, wrought iron, malleable iron, or tough bronze. Frequently when only a few pieces are to be milled, it is not used, and some steel castings are milled without oil; also in cutting cast iron it is not used. For light, flat cuts it is put on with a brush, giving the work a thin covering like a varnish; for heavy cuts it should be led to the mill from the drip can that is usually sent with each machine, or it should be pumped upon or across the mill when cutting deep grooves, milling several grooves at one time, or, indeed, in milling any work where, if the chips should stick, they might catch between the teeth and sides of the grooves, and scratch or bend the work.

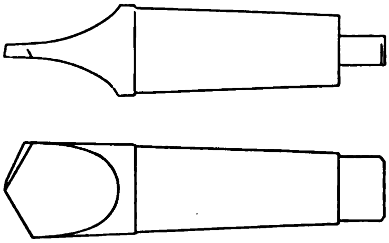


Fig. 219.

The Brown & Sharpe Co. recommend the use of lard oil in milling. Any animal or fish oil, however, may be used, and then separated from the chips by the use of a centrifugal separator, or by dumping into a tank of water. In the latter method, the chips fall to the bottom and the oil rises to the top, whence it may be drawn off with but little waste.

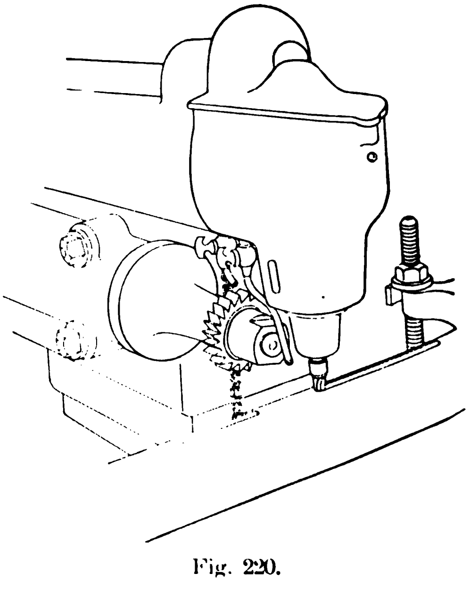


Fig. 220.

One of the operations for which the miller is particularly adapted is the laying out and drilling of holes which require to be accurately placed. The grad-

174

uated feeds of the milling machine allow the distances to be set off as closely as .00025 inch, and holes can also be drilled to a given depth with equal accuracy. In starting holes, it is best to use a spotting drill, Fig. 219, which is extremely rigid and perfectly true. The spot made should be slightly greater in diameter than the drill to be used. The drill should be what is known as reamer size, that is, $\frac{1}{64}$ inch below the standard, and the hole may then be reamed, either in one operation, using a standard reamer, or by first using a machine reamer, which is about .005 inch under size, to be followed by the standard reamer. It is evident that holes thus drilled and reamed will be parallel, and, by using the vertical head, holes can be drilled at right angles in like manner. When extreme accuracy in holes is demanded, a boring bar may be used after the drill in order to correct any error due to the running of the drill itself.

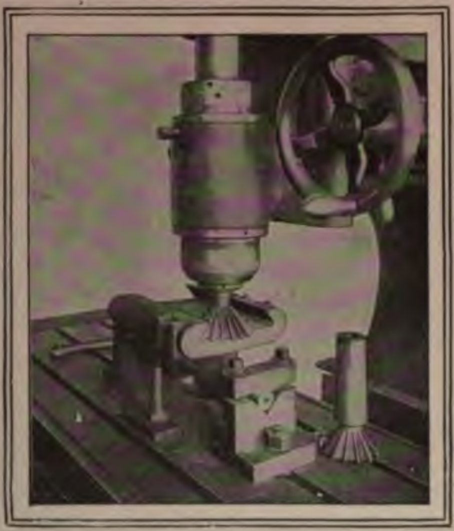


Fig. 221.

Splining Shafts. Another operation suited to the milling machine, although sometimes performed on the shaper or planer, is that of splining shafts. The slots in the table give the proper alignment to the shaft, the cutter can be set with correct relation to the axis without difficulty, and the spline cut full depth at one operation. The only objection to this form of spline is the curve at the end due to the shape of the cutter. An end mill in the vertical head can be used to remove this objectionable feature, and some splining machines are made, Fig. 220, which permanently carry both cutters, so that the work can be quickly shifted from one to the other.

The operation of making dovetails, which is a delicate and expensive job on the shaper, is readily performed on the milling

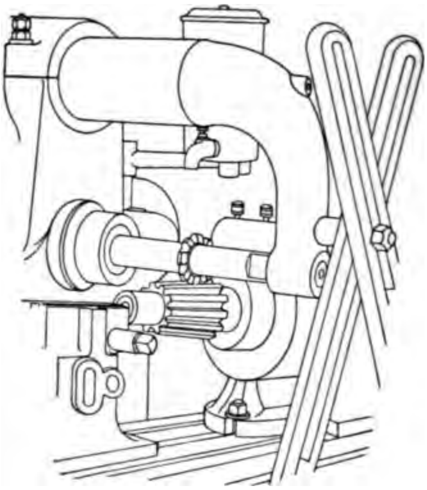


Fig. 222.

machine, especially of the vertical type, Fig. 221, the cutter being a form of end mill suited to the size and angle of the dovetail. **T**-slots are cut in a similar manner, either directly from the solid, or by following a groove made with a plain cutter.

One of the most common operations performed between centers is the fluting of taps and reamers, Fig. 222, which is done by the special cutters already referred to. It will be noticed that the cutter should be set in such a way that the cutting edge of the tap or reamer will be radial. If left as an obtuse angle, the tool will simply scrape and not cut, while if the tooth is undercut to any extent, it will be so weakened as to be liable to break.

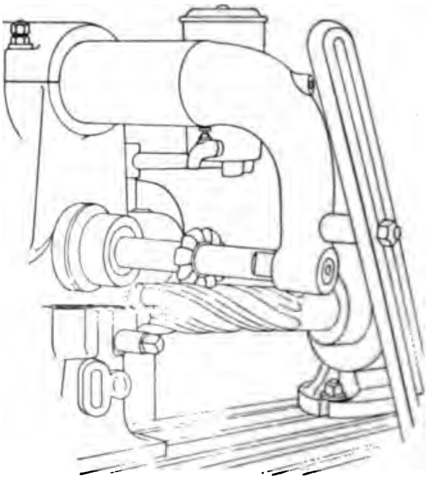
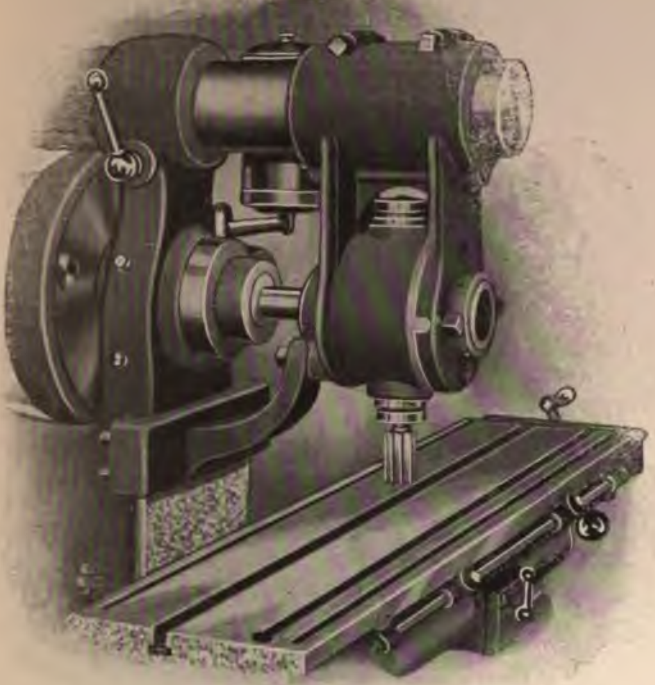
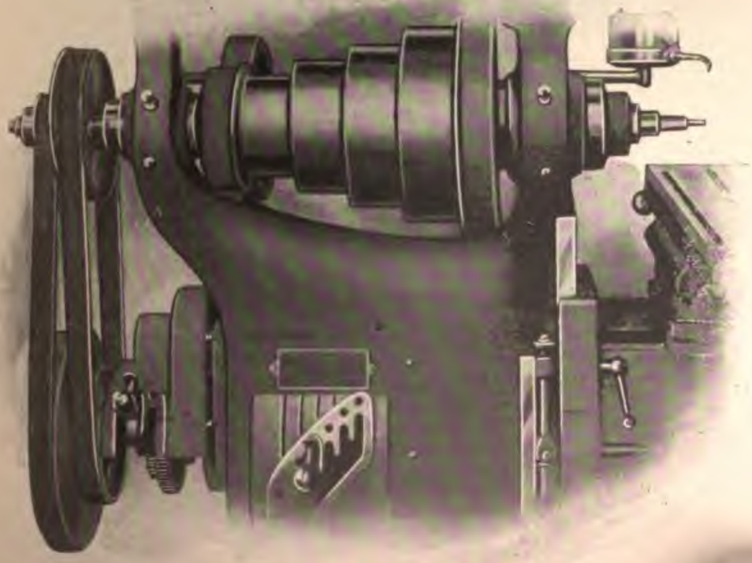


Fig. 223.

The flutes in twist drills and in spiral fluted reamers are also cut between centers, but, if the cutter is carried directly by the spindle, the operation requires a universal machine. If the cutter be carried by a vertical or sub-head of any kind, a plain machine will answer for the purpose. The angle to which the table or vertical head must be set for spiral cutting, Figs. 223 and 224, is the angle between the axis and the development of the spiral. This angle can be closely determined by the following graphical method: construct a right-angled triangle, having a base equal to the axial



VERTICAL SPINDLE ATTACHMENT.



HIGH-SPEED ATTACHMENT.

Machine Co.

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nce represented by one full turn of the spiral and a perpen-
lar equal to the circumference of the work. For strict accuracy, this circumference should be taken at one-half the depth of the flute. Draw the hypothenuse of this triangle, and the angle between the base and the hypothenuse may be closely determined by the use of a protractor, and will be the angle to which the table or head must be set. This angle can be more closely and quickly determined by a very simple problem in plane trigonometry, viz.:

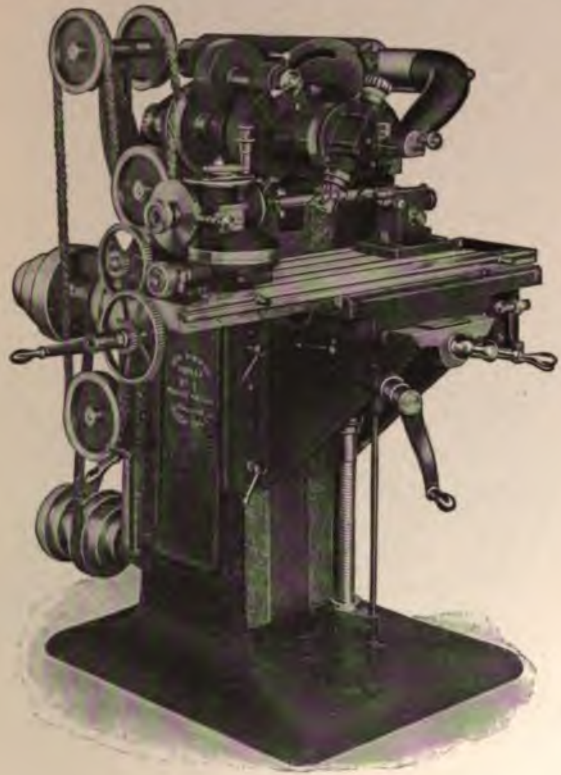


Fig. 224.

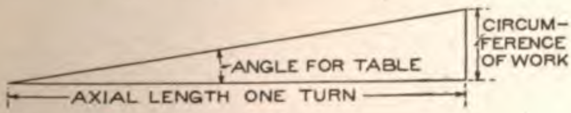


Fig. 225.

finding the sine of the angle. To do this, divide the perpendicular of this triangle by its base, and obtain the value of the angle from a table of sines.

Spirals. The cutting of spirals requires another operation different from ordinary work. In addition to the angular setting, the work must be rotated, in order to produce the spiral, as well as fed forward to the cutter. This rotation of the work must be positive, which means geared, and one rotation of the work will, of course, equal the pitch of the spiral, which is usually expressed as one turn in "n" inches. After cutting one spiral groove, the work is turned and indexed the same as in plain milling.

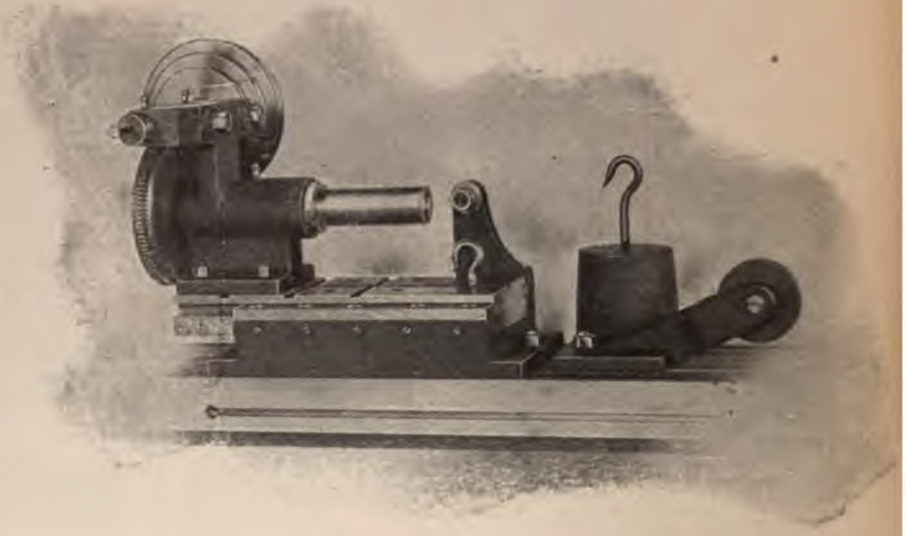


Fig. 266.

Cams. Both open and closed cams can be readily cut on a plain milling machine by the use of the cam-cutting attachment, Fig. 226, which nearly all makers are able to furnish. The outline of the cam is first laid out and worked down by hand on a plain disc, or male leader, as it is termed. This leader and a suitable blank are mounted, with their outlines coinciding, on the spindle of the cam-cutting attachment. A cam roll of the size to be used is mounted on a stationary roll stud, and an end mill of the same diameter, or enough larger for clearance, is mounted in the milling machine spindle directly opposite the cam roll. The spindle of the cam-cutting attachment is mounted on a carriage, which, by means of a weight over a pulley at the end of the milling machine table, is always kept with the leader in contact with the cam roll. A worm and worm gear are used for rotating the attachment, and thus the spindle approaches or recedes from the cam roll according to the shape of the leader. When cutting closed cams, it is sometimes desirable to use the hand-made male leader as a form from which to make a closed or female leader. This female leader will surround the cam roll in such a way that, even if the weight should fail to act, no serious damage can be done to the blank. The cutting of face cams differs from the above description only in that the spindle of the attachment is at right angles to the spindle of the milling machine instead of parallel to it. The leader and cam roll are used in the same manner as before.

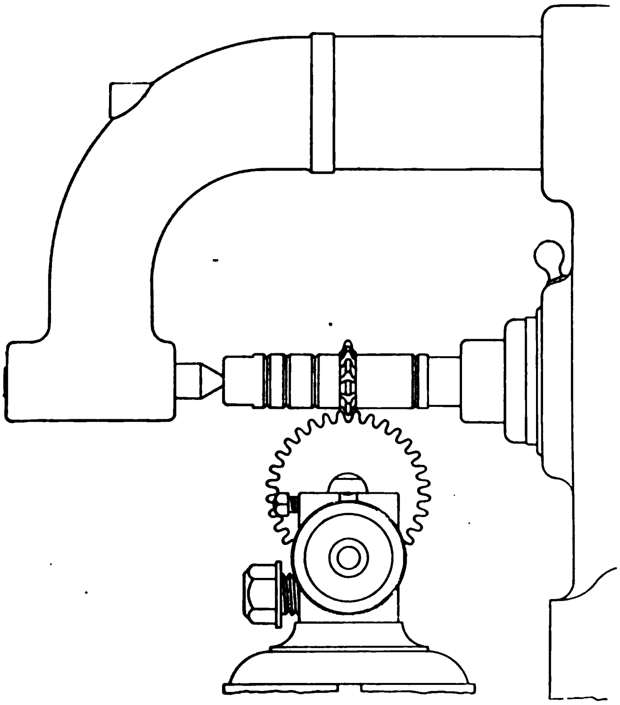


Fig. 227.

Gears. The cutting of gears of all descriptions was formerly done on some type of milling machine. although now each type of gear has its special, and, in many cases, automatic machine.

The cutters for spur and bevel gears are of two types, producing the cycloidal and involute tooth. For each pitch, the cycloidal system requires twenty-four cutters, while eight cutters suffice for the involute system. These cutters are plainly marked with the style of tooth, pitch, and number of teeth for which it is suitable. Some cutters are also marked with the whole depth of the tooth expressed in thousandths of an inch. The gear blanks, having been very carefully turned as to outside diameter, are mounted on an arbor between centers, and the cutter placed so that its central plane passes through, and is parallel to, the axis of the arbor. The knee is now raised until the cutter, when rotating, just touches the outside of the blank. The work is now moved out from under the cutter, and the knee raised, using the graduated dial, an amount equal to the whole depth of the gear tooth.

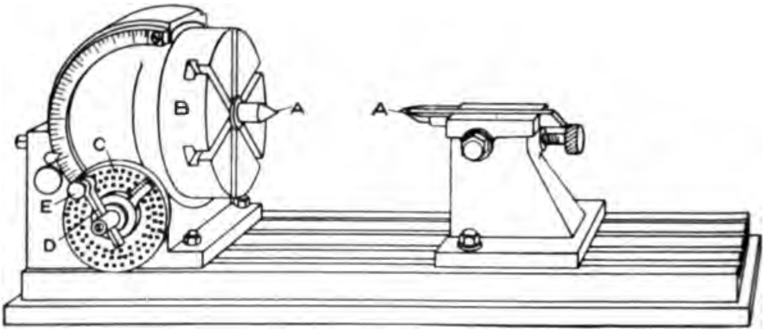


Fig. 228.

With the exception of the indexing, the gear is now ready to be cut, Fig. 227.

In order that the gear may be accurately and quickly set for each tooth, a dividing head is used, which is shown in Fig. 228. The mandrel upon which the gear is mounted is hung upon the centers A A, and firmly fastened to the spider B. The index plate C is geared to the spindle that carries the spider B; the index plate is drilled with a large number of holes. These holes are arranged in circles, and are accurately spaced at equal distances apart. The arm D carries a stem E, having a knurled head at one end and a pin at the other. The pin is held in one of the holes of the index plate by a spring. The arm D can be moved to any desired position, relatively to the index plate, and there fastened.

When a gear is to be cut, the arm D is moved so that the pin is opposite a row of holes the number of which is the same or a multiple of the number of teeth to be cut. Thus, suppose a gear with 45 teeth is to be made. The pin may be set opposite the circle of 90 holes. Assuming that the ratio of revolution between D and B be 40 to 1; $\frac{1}{45}$ of a revolution at B requires $\frac{40}{45}$ of a revolution at D. The pin E must, therefore, be moved $\frac{40}{45}$ of 90 holes, or 80 holes, for each tooth cut.

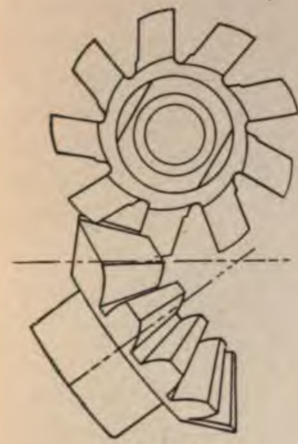


Fig. 229.

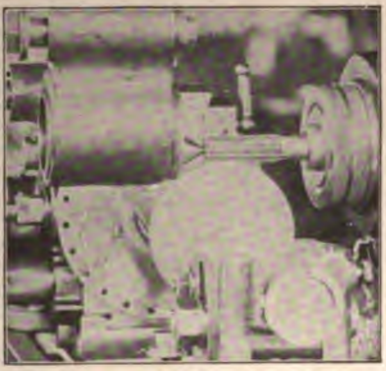


Fig. 230.

Bevel gears are held on an arbor in the dividing head, which is swung up to bring the bottom of the tooth parallel with the table, Fig. 229. As all parts of the tooth of a bevel gear are elements of a cone, it is evident that both the tooth and the space should vanish at the apex of the cone. No solid cutter, therefore, can do more than give an approximately correct shape to the tooth. Sometimes two cuts are made in order to more nearly approach perfection.

Spiral gears are cut in the same manner as any other spiral that is, by using the angular setting of the head or table together with positive rotation of the work.

Worm gears can be hobbed out by two different methods. The more common way is to gash the blank with a stocking cutter, then mount it on an arbor held loosely between centers so that the hob, when sunk into the gashes, will rotate the blank. The blank is raised slowly until the hob reaches the proper depth. A more accurate method is to positively rotate the blank at a speed corresponding to the pitch of the hob, and raise the rotating blank against the rotating hob until the proper depth is obtained. This method requires no preliminary gashing. See Fig. 230.

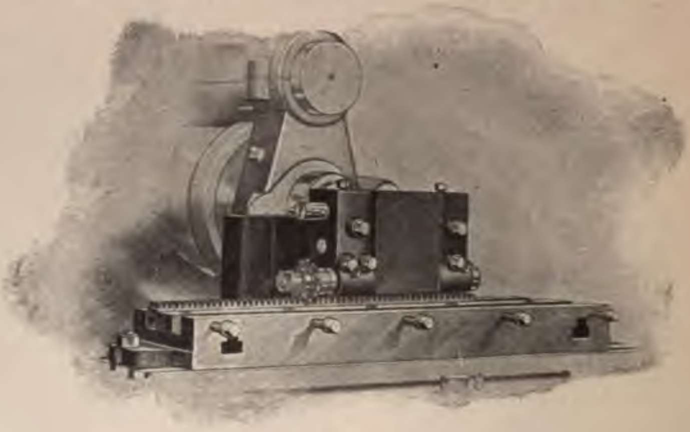


Fig. 231.

Rack cutting requires a special attachment, Fig. 231, so that the cutter spindle may be carried at right angles to the length of the table.

THE GRINDING MACHINE.

When greater accuracy than that obtainable on the milling machine or the lathe is required, recourse is had to grinding. The operation depends upon the abrasive or cutting qualities of emery, corundum and carborundum. With work properly held to a solid grinding wheel it is not difficult to attain great accuracy. By means of the grinding machine, parts may be economically finished even in hardened steel that could not possibly be machined on such shop tools as the lathe, planer, or shaper. One type of machine used for this purpose is shown in Fig. 232. With such a machine, round surfaces may be ground so that the variation from the nominal diameter is less than .0001 inch.

The grinding machine consists of a strong base A, upon which there is mounted a headstock B and a tailstock C similar in action to those of an ordinary lathe. Back of this there is an emery wheel driven by a separate belt. The principle of operation, for round surfaces, is that the part to be ground is put upon the centers, and driven exactly as in the ordinary lathe. The only additional precaution to be taken is that the driving apparatus should be secure, so that there is no looseness of the parts. This insures a continuous motion for the piece with no possibility of any black-lash. The piece turns towards the operator, and the emery wheel runs in the same direction. The two surfaces of wheel and work in contact are, therefore, moving in opposite directions.

The head- and tailstocks are mounted upon a traveling table D; this table moves back and forth in the same manner as the platen of a planer. It is made to stop automatically at each end of the stroke.

When work is being done, the piece is centered, with its axis parallel to the line of travel of the table. With the piece and emery wheel in motion, the former travels to and fro in front of the lathe. The wheel is then gradually moved forward until it has ground the work down to the size required.

It is not intended that large amounts of metal shall be removed by this machine. Its object is to reduce to accurate dimensions the work that has already been turned in the lathe. The proper method to pursue is to turn the piece to as nearly the required diameter as possible in the lathe, care being taken that it is left a trifle large. This may be .01 inch on each 2 inches of diameter. The surplus metal may then be removed by grinding. In the machine illustrated in Fig. 232, the transverse movement of the wheel-stand is adjusted by a hand-wheel graduated to read to .001 inch on the diameter of the work. The machine is also provided with an automatic cross-feed, which gives a range of advance of the wheel varying from .00025 inch to .004 inch at each reversal of the table. This feed is, furthermore, so arranged that it can be automatically released at any point.

This method of finishing is also used for pieces that have been case-hardened. Case-hardening always warps the metal to

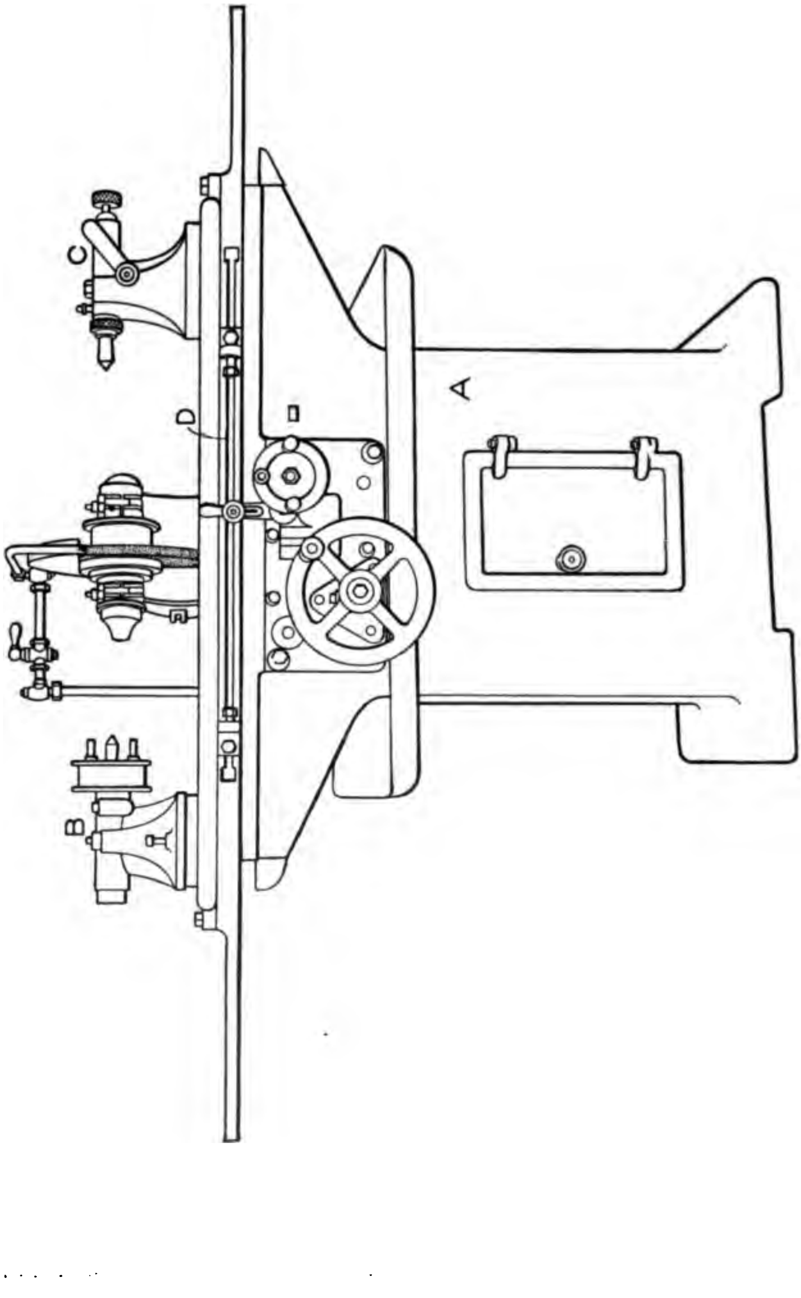
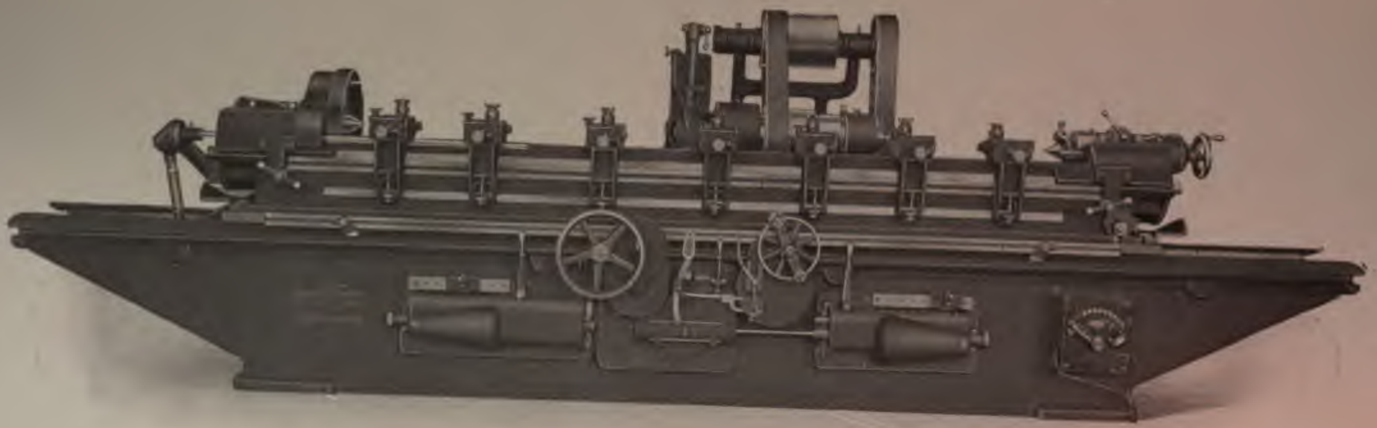


Fig. 232.



FRONT VIEW OF GRINDING MACHINE SHOWING ELECTRIC DRIVE.
Norton Grinding Company.

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which it is applied. Grinding is resorted to in order to reduce it to the proper shape. An example of this may be taken in the method used in the manufacturing of wrought-iron locomotive crank-pins. The pin is forged and turned to as near the working size as possible. It is then case-hardened and ground to exact truth and dimensions.

Grinding is also used for truing work that comes from the lathe. The lathe does not turn its work round, owing to difference in the density of the metal, the variation of the cutting speed, the dulling of the tool, the lost motion on the centers and in the spindle, and the springing of the work itself due to the pressure of the tool.

SPEED OF GRINDING WHEELS.

Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute
1	19,000	5	4,400	14	1.580
1½	12.500	6	3,700	16	1.380
2	19,000	7	3.160	18	1,230
2½	8,800	8	2,770	20	1,100
3	7.400	9	2,460	22	1,000
3½	6.300	10	2,210	24	920
4	5.500	12	1,850	26	850

The grinding machine remedies this to a great extent. Partly because only a very slight pressure is brought against the work; partly because of the greater delicacy of adjustment of the grinding machine as compared with the lathe.

The method of grinding flat surfaces is practically similar to that used for round. The work is bolted to the table and moved to and fro beneath the emery wheel, which is given a transverse movement so as to cover the whole of the surface to be operated upon. The surface speed of the wheel may range from 3,000 to 5,000 feet per minute.

The above table gives the maximum speeds of caborundum wheels of various diameters.

The accuracy of grinding renders the use of fine measuring tools a necessity. The micrometer caliper, especially with the vernier graduation, is best suited for this work.

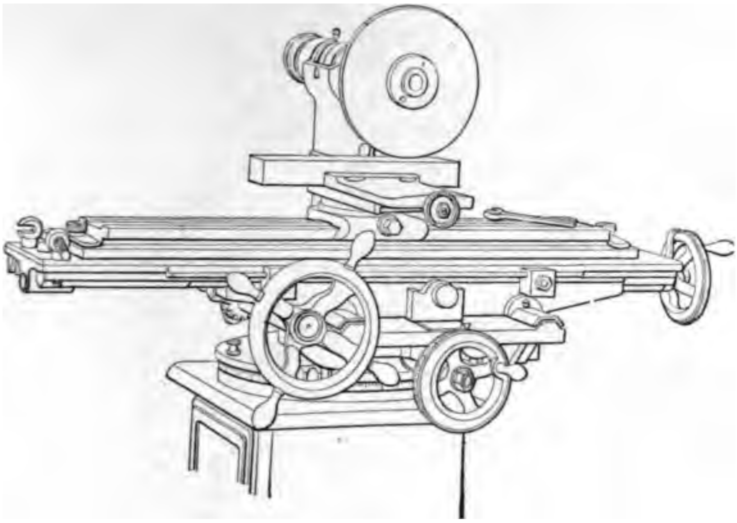
While grinding is the only method of finishing some materials, such as hardened tool steel, and the most accurate way for finishing any kind of stock, its value as an economical method is just beginning to be recognized. The general method of finishing lathe work has been to take a roughing cut with about $\frac{1}{16}$ inch feed, then a finishing cut with about $\frac{1}{100}$ inch feed, and then file to remove the tool marks. In the majority of cases it is more economical as well as more accurate to take a roughing cut with $\frac{1}{8}$ inch feed to within $\frac{1}{32}$ inch of the size, and then finish by grinding.

In some cases it is possible to get excellent results by grinding to size direct from the bar without previous turning.

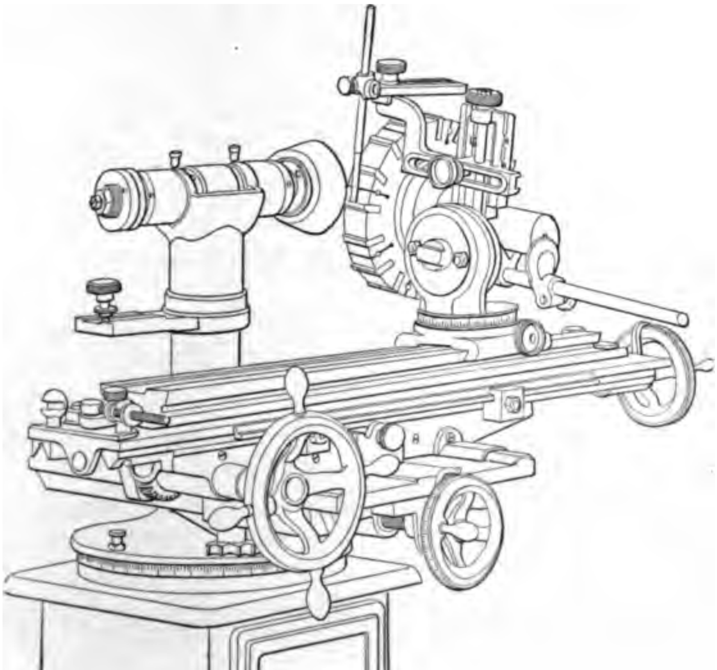
Lapping is a term applied to a particular method employed in the grinding out of holes. The lap consists of a cylinder of soft metal run rapidly inside the hole to be lapped and covered with emery and oil at the same time. The surface of the lap should invariably be of soft metal. It may be made of copper, or it may be an iron bar with a covering of lead or tin. It should be turned slightly tapering at each end, so that it will enter the hole. At the middle, it should be a tight fit.

The end of the bar is run through the hole and set on the lathe centers with a dog to drive it like an ordinary mandrel. It is covered with oil and sprinkled with emery. The lathe is then run at a high speed and the work moved to and fro over the lap. Light pieces may be held in the hand. When this is done, care should be taken to turn the piece so that the grinding may be even over the whole circumference. The tendency is, when holding work in the hand, to allow it to rest upon the top of the lap; this causes the grinding to be done on one side of the hole unless the piece is frequently turned. Laps may be used for grinding holes true and parallel. For this purpose the work should be accurately centered with the lap and firmly bolted to the lathe carriage. The lap is then run at a high speed and the work moved to and fro over it.

Laps are sometimes used for grinding flat surfaces. In such cases they are in the form of disks. They are put on the lathe



UNIVERSAL VISE ARRANGED FOR SURFACE GRINDING.



SHARPENING TEETH OF LARGE FACE CUTTER.
Norton Emery Wheel Co.

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spindle in the place of the faceplate. The work is then pressed against the disk. As the outer edge of the disk has a higher speed in feet traveled per minute than those portions nearer the center, the grinding is more rapid at the edges. The work must, therefore, be constantly turned if it is held in the hand. The best way is to clamp it firmly on the lathe carriage, and press it against the lap by means of the hand feed.

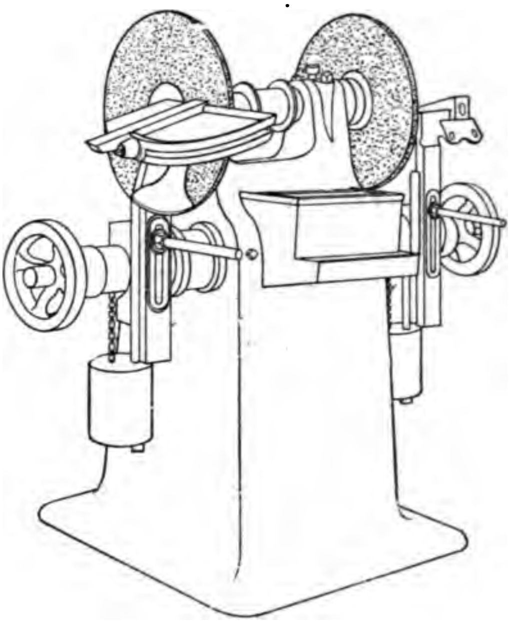

Fig. 233.

Laps for flat surfaces have grown in favor so rapidly that special machines have been made to do this work. The construction of the disk grinder can be so readily seen from the illustration (Fig. 233), that a detailed description does not seem necessary. For finishing small flat surfaces, especially those which have been hardened, this machine has become an important factor in the modern shop.

LAYING OUT WORK.

Laying out work is one of the most important details of machine shop practice. Ordinarily all work is laid out. The exceptions are where certain pieces are worked from templets, and in these cases the templet is laid out from certain points on the casting, forging, punching, or whatever is used for the work in hand.

The simplest form of laying out work is to be found in the centering of round bars that are to be turned in the lathe. In this case the end of the piece is chalked. Use a pair of hermaphrodite calipers, set the points A and B so that their distance apart is a little more than the radius of the piece. Place the caliper leg at three points on the circumference, A, B, and C (Fig. 234), and describe from each the arcs of circles A′A′, B′B′, and C′C′, respectively. Then with the prick punch mark the point indicated by the small circle in the center. This will be the center. To test its accuracy, place the divider leg in the prick punch mark and see if the caliper leg will just touch the bar over its whole surface.

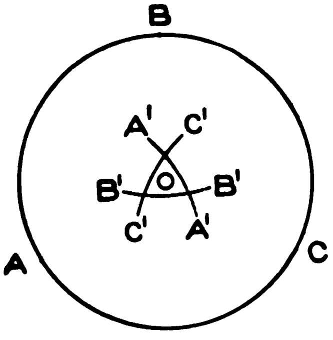

Fig. 234.

Before drilling, the center should be emphasized with a center punch.

The center square may be used for this operation, as the center can be easily located at the intersection of two diameters drawn nearly at right angles. In some cases it is better to lay the shaft in V blocks on a plate and use the surface gauge, drawing at least two lines through the center of the piece.

It is usually necessary to cover the surface of the work where lines must be visible, with chalk, white lead, or copperas, before any laying out can be done; but in cases of this kind it is usual to mark directly upon the end of the bar. Before drilling, the center should be emphasized with a center punch.

The locations for holes should be at the intersection of lines in order to be plain. After marking the center with a prick punch, take a pair of dividers and scribe a circle on the prepared surface concentric with the center already located. This circle should be about the diameter of the hole to be drilled, and in many good shops it is the custom to draw another circle concentric with the first and about $\frac{1}{8}''$ larger in diameter. This outer circle is called the reference circle, and is for the benefit of the inspector when it becomes necessary to place the responsibility for a misplaced hole. These circles may be marked with at least four prick punch marks, as shown in Fig. 168, in order to indicate the position of the circle in case of the obliteration of the line. The center is then deepened by the center punch and the hole drilled. In laying out work, the first thing to do is to "snag" the work; that is, remove the ridges of the casting caused by the pattern being made in two or more parts. For small castings a coarse file is generally used, while for large work the cold chisel is used. In many shops the cold chisel is operated by compressed air.

In laying out work for the planer and milling machine great care must be exercised. It is necessary that there should be a base line to which the lines may be referred. It depends on the character of the work as to how this should be done. Sometimes it is quite sufficient to lay off the base line parallel to one side of the casting or forging. If the side thus used is to be finished, then the base line should be located at the proper distance from it to allow for the finishing. The amount required varies with the character of the casting or forging; this has been fully explained. Usually there is some outline of the rough piece that will serve as a guide.

As an example of the laying out of work, take the valve and steam chest seats shown in Figs. 235 and 236. The work is to be done on a planer. The cylinder has probably been bored. It is then placed on the planer, and so set that the center line through the cylinder is parallel to the platen of the planer. The first machine work to be done is the taking off of the roughing cut from the face A. This face is to be planed down to a certain height above the cylinder center; this height may be marked on the edge of the valve seat by the prick punch mark B. If the surface C is to be planed at the same time, its height is indicated by the prick punch mark D. These points may be located by means of the surface gauge. Set the gauge on the platen and elevate the point to the proper height. Move it so that it will touch the side of the casting at the proper point, and make the marks B and D accordingly. When the surfaces A and C have received the roughing cut, the plan may be laid off as in Fig. 236. With a square having a suitable length of blade, locate the points G and H directly over the center line of the cylinder. Cover the

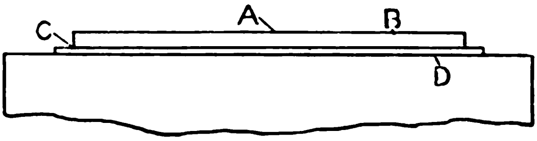

Fig. 235.

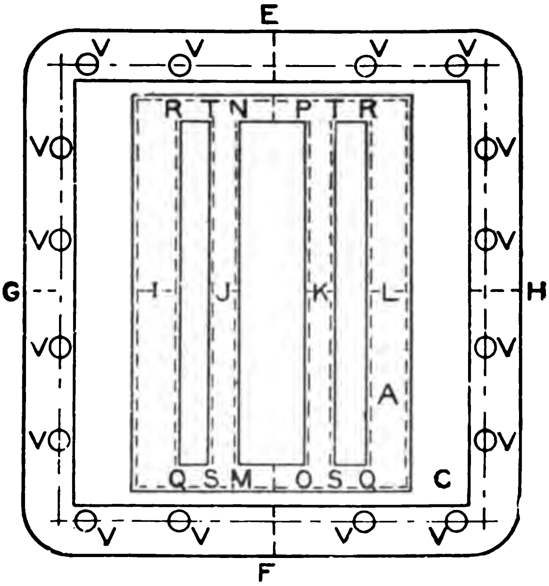

Fig. 236.

surfaces A and C with chalk where lines are to be drawn. Draw the lines I, J, K and L on the surface A, between G and H. Through the center of the side of the exhaust port draw the lines E and F at right angles to GH. This is done with a scriber. Lay off half the width of the exhaust port on either side of E and F, and draw the lines MN and OP parallel to E and F. In like manner, draw the lines QR and ST for the limits of the steam ports. All of these lines are to be emphasized by the use of prick punch marks as indicated.

If the sides of the valve seat are to be finished, the line to which the metal is to be cut is indicated in the same manner. Finally the holes VVV, etc., for the holding down studs of the steam chest, are to be laid out. The center lines are first drawn; then the centers of the holes are marked. After which the circles for the holes are drawn as already described.

Work is rarely laid out for the lathe. It is not necessary that it should always be done for the planer. Laying out is employed where accuracy is essential, and, where it is possible to secure the proper dimensions, with the piece to be operated upon in position on the machine.

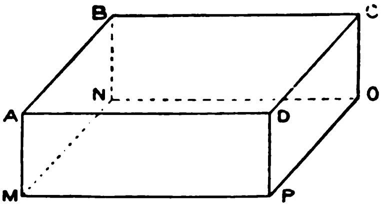

Fig. 237.

The man who has charge of the work of laying out should have some knowledge of the elementary principles of geometry, he should also have some knowledge of drawing, and should, of course, be able to read drawings.

A few general suggestions may be given regarding work to be finished in the vise on either the planer, shaper, or the milling machine, where several faces are to be finished at right angles to one another. Referring to the rectangular block of Fig. 237, the block is first placed in the vise with the face MNOP down, and the face MADP against the fixed jaw. The face ABCD is then machined, and the work turned so that ABCD is against the fixed jaw and MADP down. With the block in this position, NBCO is worked, making NBCO at right angles to ABCD. With ABCD still against the fixed jaw, and

NBCO down, surface MADP is next worked. This brings two edges at right angles to the same side and parallel to each other. Then, placing ABCD down and either MADP or NBCO against the fixed jaw, surface MNOP is generated parallel to ABCD. This leaves the ends to be finished. The vise is swung so that the fixed jaw is at right angles to the line of motion of the tool, and on the planer and shaper, they are finished by using the vertical feed. In the two last named tools, the tool holder is swung so that the tool will clear the work easily on the return stroke.

In working cast iron, it is well to chamfer the edges with a file. If this is not done, the metal will break off when the tool reaches the end of the cut, leaving a ragged edge. The depth of the chamfer depends on the amount of metal to be removed.

Fitting is the term generally applied to the hand work necessary in assembling machinery after all the machine work has been done. Filing, either in the vise or lathe, and scraping are the operations usually required, although the hammer and chisel are sometimes used. As hand work costs much more than machine work, the machining is done as closely as possible to make the hand work a very small item.

SHOP SUGGESTIONS.

In the regular work of any shop, occasions are constantly arising for the determination of the best method of doing work. The success with which the desired end is attained depends upon the skill and judgment of the man in charge. While it is impossible in a limited space to give instructions regarding every possible emergency that may arise, a few suggestions regarding shop practice will be valuable.

Pening consists in the stretching of the metal on one side of a piece of work in order to alter its shape. There is a wide difference between pening and bending. For example, suppose the curved or warped piece in Fig. 238, is to be straightened. If it were to be bent until it were straight, it would be placed on the blocks A with the concave surface down, as shown by the dotted lines. It could then be struck by the hammer and driven down past the line of support, and strained so that it would remain approximately straight. Such a method of straightening could not be applied to a piece of complicated outlines. It would remain wavy. In pening to truth such a piece as shown in Fig. 238 it is laid on an anvil with the convex surface down. It is then struck with the pene of the hammer on the concave side. The blow must be quick and sharp. The result is that the metal is stretched at the point where the blow is struck. By working successively over the whole surface the concave side is stretched so that it is equal, in its dimensions, to the convex side. The piece then becomes straight and will so remain. A skillful use of the hammer will straighten almost any warped piece of thin metal.

Drilling Hard Metals. It is sometimes desirable to drill a hole in very hard metal. To do this the drill must be made very hard; it must be run at a very slow speed; it must be forced against the work as hard as possible without breaking the point, and it must be provided with an abundant supply of oil. For excessive hardening of a drill, it may be heated to a dull red heat, preferably in a charcoal fire, and quenched in mercury instead of water. It will also assist in the operation if the surface of the metal to be drilled is nicked with a cold chisel before work is begun. In some cases turpentine, in place of oil, may be used with beneficial results.

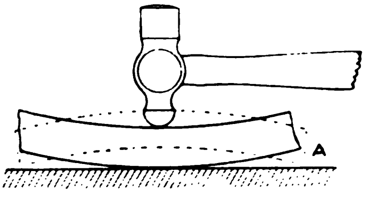

Fig. 238.

Thin chilled cast iron may be softened by placing a small piece of sulphur on the place where a hole is desired and then heating slowly to a dull red.

Glass may also be drilled. There are two methods: one is to use a flat drill moistened with camphor and turpentine, and the other is to use a copper tube with No. 60 emery or carborundum and oil. In the last method, drill half-way through, reverse, and drill to meet, removing the fin at the center with a round file wet with water or turpentine.

Grinding Valves. This is a kind of grinding that is usually done by hand. It consists of fitting a valve and its seat so that they are in metallic contact. In its results it is the same as scraping. The process is very simple. The valve is coated with oil and some fine emery sprinkled over it. It is then put on the seat and worked back and forth or revolved. The emery serves to grind off the high surfaces of each. After grinding for a time, remove the valve and wipe both surfaces clean. The metal on each will show where they have been in contact. When these indications appear over the whole of the surface, or in a continuous ring about the seat of a circular valve, the work is completed.

To generate a surface plate it is necessary to work with three at the same time. For the sake of making the explanation clear they will be called A, B, and C. After the plates have been planed, a straight edge should be laid on each. A straight edge is merely a piece of flat steel having one or both edges true and straight. Set the straight edge on the plates in all directions. If it touches over its whole length in all positions, then the plates are ready for scraping. If it touches at the edges of the plate and is clear in the center, the former are high and should be filed down. If it touches in the center and rocks to and fro, the plate is convex and the center must be filed down. After the plates have been filed to truth as far as truth can be indicated by the straight edge, they are ready for scraping.

Now take plates A and B and place them face to face. Strike a blow on the upper one, and it will cause a jarring sound to be heard. This shows that the two are not in perfect contact. Smear the surface of plate A with a thin mixture of red lead and oil. Cover the surface evenly and thinly. Then rub the two plates together, and where the red lead rubs off on to the surface of plate B the two come in contact. Take the scraper and scrape off a little of the metal from each of the plates where they have been in contact. Wipe off plate B, and again smearing plate A, proceed as before. Continue this process until the two surfaces are in contact over their whole areas. This does not prove, however, that they are flat. They may be in contact, as required, if A is convex and B is concave. To test this the third plate is necessary. Smear plate B with red lead and scrape C to fit it. Do not touch A. It is evident that A and C will then be alike. Bring them together. If they are both convex they will roll over each other. If they are concave they will bear at their edges and not touch in the center. They will appear to be out of truth by twice the actual amount. Scrape off the contact points of A and C. Remove as nearly as possible the same amount of metal from each. When these two plates have been brought so as to be in contact over their whole areas, lay plate A aside and scrape B until it fits C, but do not touch A. Then try A and B together. If they do not touch over their whole areas, treat them as before described for A and C. Then introduce C again. Continue this alternating process until the three plates form a bearing over the whole of the surface of each of the other two.

During the latter part of the process, use alcohol instead of red lead. This will leave clean, bright spots at the points of contact.

Fitting Brasses is a piece of work that is now usually done on a machine, but which is sometimes done by hand. Brasses that are to be used for connecting rods, and which are made in two pieces as shown in Fig. 239, have a tendency to warp after the machine work has been done upon them. The difficulty arises from their closing along the diameter A. Thus if the brass is finished, and the hole bored out to the proper diameter, and is then cut apart on the line CD, it will be found, shortly afterwards, that the diameter A is less than the diameter B. It may, therefore, be necessary to bore the hole somewhat larger than the working diameter. The kerf made by the saw will usually allow the parts to be drawn together along the diameter B so that it will more than make-up for the shrinkage at A. The hole can then be scraped to fit the pin. The brasses should always be keyed solidly metal to metal. This avoids a wear of the sides and edges of the metal due to the thrust of the rod.

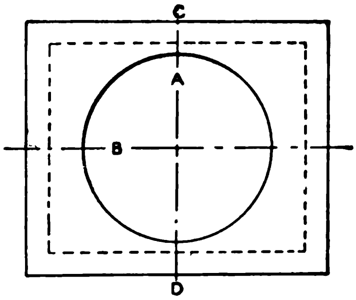

Fig. 239.

Joints. Where a gas or liquid is to be retained in a pipe or other vessel without leakage, a tight joint is necessary. The method of grinding valves to their seats has already been explained. In that case it was shown that a metallic contact between the valve and its seat is all that is required in order to make it a tight joint. Two surfaces that have been scraped to fit will also accomplish the same purpose. This is frequently too expensive an operation to be performed, especially on rough work. In such places a soft material may be interposed between the two surfaces. Where the joint is to be a permanent one and is not to be taken down, the red lead joint is usually employed. This consists in the use of a mixture of red and white lead between the joints. To ordinary white lead ground in oil add enough dry red lead to make a paste that can be spread without sticking to the blade with which it is applied. After the mixture has been made, it will be improved by pounding it well with the hammer. It may then be laid between the two pieces of metal forming the sides of the joint and the latter be drawn together. Red lead joints are extensively used in pipe fitting. The red lead has a tendency to rust the iron with which it is in contact, and thus form a very tight connection between the two pieces. Where provision is to be made for taking down the joint at a future time, it is better to use a graphite paste made for the purpose. This does not rust the metal; it forms a perfectly tight joint and one which may be taken down without difficulty at any time.

Joints that are subject to occasional disconnecting can be best held by a disk of rubber packing. The latter is cut to fit the flanges between which the joint is to be made, and they are then drawn tightly together.

Joints that are to be frequently taken down are usually packed with a piece of copper wire. Such a place is the joint between the steam chest and cylinder of a locomotive engine. A groove is cut in the two surfaces and a copper wire is laid therein. This wire should be about $\frac{1}{4}$ inch in diameter. Its size, however, depends upon the joint to be packed. The ends of the wire are soldered together so that no leakage may occur past the ends.

Another form of joint is the rust joint. This is always permanent in character. The making of such a joint consists in rusting the two surfaces together. The following are the proportions by weight of the rusting material: 100 parts of iron turnings; 1 part of sal ammoniac, and ½ part of sulphur. The setting of the joint can be hastened by increasing the amount of sal ammoniac from 15 to 25 per cent. Mix the ingredients thoroughly and just cover them with water.

Fluting Rollers. Where feed rollers such as those used in wood-working machinery are to be turned and fluted, the turning should always be done first. This insures a continuous surface for the cutting tool. Where old rollers are to be re-turned and fluted, the same rule applies. The fluted surface may be turned to size. The lathe tool will break the edge of the ribs away, but when the fluting is done, these edges are again made smooth. The fluting can be done on a planer with a round-nosed tool. The roller should be held on centers and clamped so that each groove may be presented to the tool in succession. A planer center, as illustrated in Fig. 178, affords a convenient method of holding and turning the work.

Scale. Whenever a piece of cast iron is to be turned, the point of the tool should always be made to work beneath the scale. The scale is the hard outer shell that covers all cast iron as it comes from the foundry. It is very hard and brittle. If the edge of the tool is made to work in or against it, that edge will soon be dulled. If it is beneath it, the raising of the chip cracks and removes the scale.

Pickling. Where castings are to be worked, either in the lathe or planer, to dimensions only a little less than that when rough, they should be pickled. This consists in washing them with a solution of sulphuric acid and water. The castings may be either submerged in or swabbed with the solution. The effect of pickling is to cause the scale to drop off in flakes, leaving the metal bare, unprotected and rusty. The casting should then be washed with a sal soda solution. A good solution for this work is to use 1 part of commercial sulphuric acid in 10 parts of water.

Cold Chisels. It is well to use a coarser grade of steel for cold chisels than for lathe or planer tools. A coarse-grained metal is preferable because the continual hammering in use and redressing will gradually modify the granular structure until it is microscopic in its fineness. In dressing, it should never be heated above a cherry red, and the temper should be drawn well down so that the soft metal backs up the edge. A capacity to receive a multitude of grindings is not what is wanted. The tool must be able to endure the severe service for which it is intended. It must cut into a distorted mass of metal, where every blow gives it a shock tending to form a new arrangement of its particles. It never receives the steady pressure of the lathe tool, hence its powers of endurance must be greater.

Lining Shafting. In equipping a shop, the first work of the machinist is the erection of the shafting. The main line should be the first laid out, and the engine, together with the jack and countershafting, must be located from it. After placing the hangers as nearly as possible in a horizontal line, the shafting should be placed in the boxes and attached to the hangers. For lining the shaft, a level and a fine grass or silk line are indispensable. The line is tightly drawn, horizontally, a short distance from the position it is desired that the shaft shall occupy, and the distance from the surface of the shaft to the line is measured and made equal near each hanger by a stick such as is shown in Fig. 240.

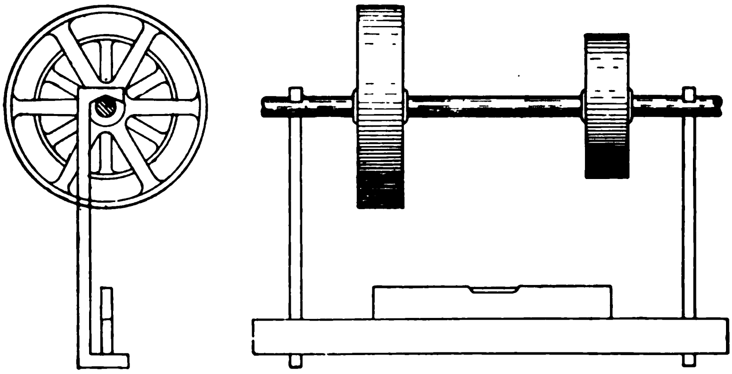

Fig. 240.

The level is used to make the shaft horizontal, and, if the hangers are adjustable in two planes, the operation is quite rapid.

When other shafting is to be erected parallel to the first, if the distance does not exceed twelve or fifteen feet, a long stick such as shown in Fig. 241 may be used by driving a nail into the

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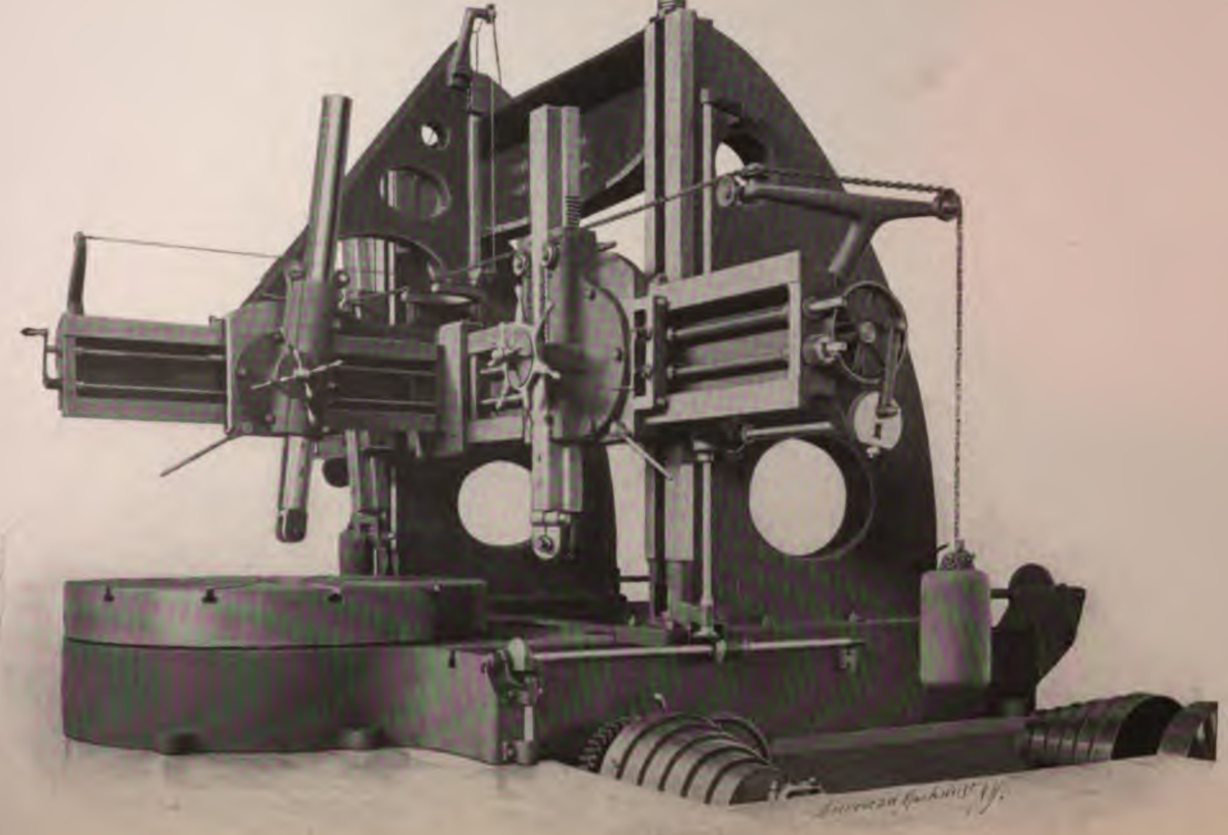

American Machinist N.Y.

BORING AND TURNING MILL.
Betts Machine Company.

end of the stick to allow some adjustment. The level is used as before.

When the distance is great, or obstacles prevent the use of the stick as suggested, a line may be drawn on the floor of the shop by dropping a plumb line from near the ends of the first shaft and connecting the points located. Another line, directly under the desired location, may be drawn by direct measurement, and the second shaft erected by dropping a plumb line to this second floor line near the ends of the second shaft. This method may be employed, with such variations as the case may demand, even though a floor or wall be between the locations.

In leveling up long lines, or around machines, or through walls, the hydrostatic level is a most convenient tool. It consists of two graduated glass tubes set in suitable bases and connected by a rubber tube. When the rubber tube is filled with water, and the glass tubes placed vertically on the shaft, the fluid should stand at the same gradation in each glass. These levels are made with self-acting valves to prevent the escape of the fluid.

When pulleys or hangers make the direct application of a level to the shaft impracticable, leveling hooks, in connection with a wooden straight-edge, as shown in Fig. 240 are very convenient. These may be made of wood or metal, and of lengths suitable to the case in hand.

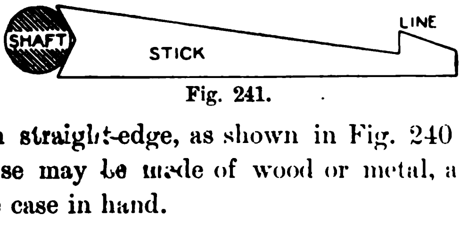


Fig. 241.

Machine Setting. After the shafting is erected, comes the setting of machines. The countershafts are first erected parallel to the main line, and with due regard to the location of the machine. The machine is then placed with its driving shaft parallel to the counter by use of the plumb line, and the platen, table, or other horizontal surface carefully leveled, in two planes, by wedging up the machine with common shingles. It is then secured to the floor by lag screws.

When the machines are very heavy, and stone or masonry foundations necessary, anchor bolts are built into the foundation at suitable points or holes drilled for expansion bolts. The machine is then lined and leveled as already suggested, but the bottom of the machine is usually a rough casting, the top of the stone foundation is still rougher, and as the wedges are likely to slip out under the jarring of the machine, a permanent support must be provided. This may be done by pouring melted sulphur beneath the bed. To do this, build a dam of clay or sand all around the bed and about 2 inches high. Melt ordinary stick sulphur or brimstone in ladles, and pour in at several points at once. Keep the space flooded until the dam is well filled, and allow it to harden. This will occur very quickly, after which the dam may be removed and the sulphur cut away from the edge of the machine. Care must be taken that the temperature of the sulphur is as high as possible before pouring. Unless this is done it will cool and set before reaching the inmost recesses beneath the machine. It will then crumble because of insufficient bearing surface to carry the imposed weight. The nuts are then screwed down on the bolts and the machine is secure.

Belting. The shafting and machines are usually driven by belting, and a few remarks on this subject may be desirable. Leather is the material generally employed, and the belting may be from single to six-ply in any suitable width. Single belting has a flesh and a grain or hair side, and should be run with the grain side in contact with the pulley. The ends are cut square, and fastened by hooks, coiled wire, or rawhide lacing.

Leather belting is injured by water, steam, oil, and temperature above 110° F. Where such conditions exist, cotton belts, faced with thin leather, or rubber belts may be used. These belts are cheaper than leather, are about as strong, and will transmit power as effectually; but they will not stand mutilation of the edges. This is a point of prime importance, and prohibits their use in many cases.

The power transmitted by a belt is directly proportional to its speed and width. A safe rule is to allow one horse-power for a speed of 1,000 feet per minute, with a single-thick belt one inch wide. This is a more liberal allowance in favor of the belt than is usually given, but will increase the life of the belt in far greater proportion than the increase in first cost. Double belts will transmit about one and one-half times as much power as single belts. The above rule applies to belts running over pulleys of equal diameter, or, in other words, to cases where the arc of contact is 180°. For smaller arcs of contact use the coefficients found in the following table:

90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	200°
.65	.70	.75	.79	.83	.87	.91	.94	.97	1.	1.05

To increase the power transmitted, either increase the speed of the belt by using larger pulleys, or use a wider belt.

A 3-inch single belt is running over a 24-inch driving pulley which makes 200 R.P.M. (revolutions per minute). How many H.P. will it transmit?

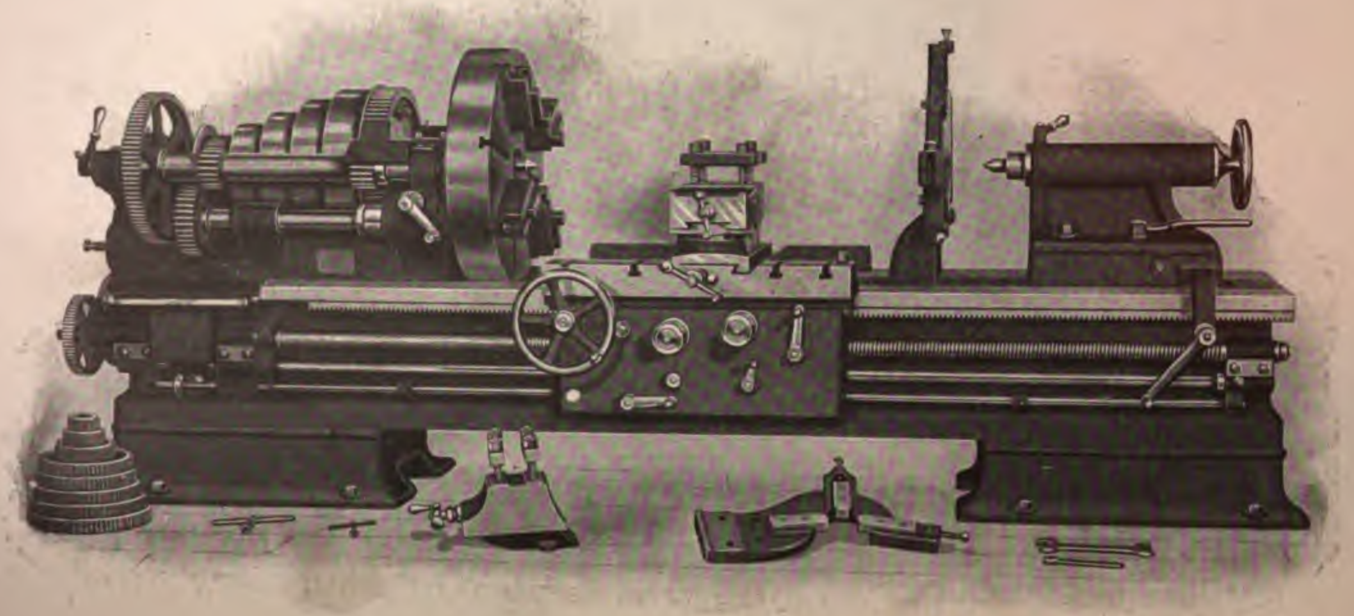
The circumference of the pulley in feet is $2 \times 3.1416 = 6.2832$ feet. As the speed of the pulley is 200 R.P.M., the speed of the belt will be $200 \times 6.2832 = 1256.64$ feet per minute. For every inch of width it will transmit $1256.64 \div 1000 = 1.25664$ H.P. Then a 3-inch belt will transmit $3 \times 1.25664 = 3.76992$ H.P. *Ans.* 3.75 H.P. (approx.).

It is desired to increase the H.P. in the above example to 5 H.P. How may it be done?

(1). By using a wider belt in the proportion of 3.75 to 5. 3.75 : 5 : : 3 : 4. *Ans.* By using a 4-inch belt.

(2). By using a larger pulley in the same proportion. 3.75 : 5 : : 24 : 32. *Ans.* By using a 32-inch pulley.

(3). By using a double belt. 1 : 1.5 : : 3.75 : 5.63. This would give a little better result than required.



32″ x 12′ TRIPLE-GEARED LATHE.
Hamilton Machine Tool Company.

TOOL MAKING.

PART I.

As generally understood, a tool maker is a machinist who has a greater knowledge of the trade than is simply sufficient to enable him to make such machines or parts of machines, as may be the regular product of the shop in which he may be employed.

The business of the tool maker is to make the tools for producing the different parts of the machine, implement or apparatus, and relates not only to cutting tools, but to jigs and fixtures for holding the work while the various operations are being done, and making the necessary gauges to determine when the different parts are of the correct size and shape. Also the making of the models for the different fixtures and gauges. In some shops where there is work enough of the two latter described classes, the tool makers regularly employed on this work are termed gauge makers and model makers respectively. Yet in the average shop the models and gauges and such special machinery as may be required are made by the tool maker.

In order to acquire any degree of success, the tool maker must not only be able to work accurately and within reasonable time, but he must have a knowledge of drafting to enable him to read quickly and accurately any ordinary drawings. Unless he can read decimal fractions readily and accurately, he will experience much difficulty when working to measurements that require accuracy within one ten thousandth part of an inch. As most of the measuring instruments used by the tool maker read to one thousandth part of an inch, and some of them to the ten thousandth part of an inch, or even closer, it will be readily seen that in laying off measurements for gauges, models, drill-jigs and similar work, a thorough knowledge of Arithmetic is essential.

A tool maker should be familiar with the accurate reading of the micrometer and of the vernier as applied to the vernier caliper, vernier depth gauge and vernier height guage. He must bear in mind when using the vernier caliper for inside measurements that it is necessary to add the amount of space occupied by the caliper points A A Fig. 1 to the apparent reading on the vernier side.

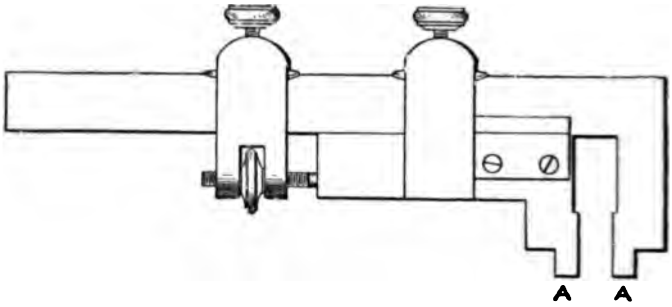


Fig. 1.

When measuring the distance between the centers of two holes as in Fig. 2, the vernier may be set so that the portions of the jaw marked A A Fig. 1 will exactly caliper the distance from B to B′ in Fig. 2. To the apparent reading of the vernier add the space occupied by the caliper points, and from this subtract one-half the diameter of each of the holes. It is necessary to caliper the size of *each hole*. Do not take anything for granted when accurate measurements are necessary. A reamer *should always* cut an exact size, but experience proves that it does not always do so. If the size of the hole is taken for granted, a variation of .002 inch means an error of .001 inch in a measurement.

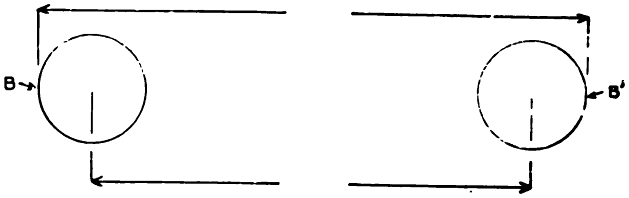


Fig. 2.

While extreme care should be exercised where accuracy is essential, there are parts of a tool where *approximate* measurements will do. If within $\frac{1}{16}$ inch is sufficiently accurate, it is folly to spend time to get a dimension within a limit of one ten thousandth part of an inch.

Approximate measurements are those made with the aid of calipers, dividers, surface guage, etc., set to an ordinary steel rule. Precise measurements are obtained by the aid of the various measuring instruments graduated to read to very small fractions of an inch. Also by the use of standard reference discs, and standard test bars, accurate within a limit of variation of $\frac{1}{50000}$ part of an inch. In using the micrometer, vernier or any of the measuring instruments supposed to give accurate readings, it is necessary to exercise great care in setting the tools. In setting the vernier it is well to use a powerful eye-glass in order that any error in setting may be so magnified as to be readily apparent.

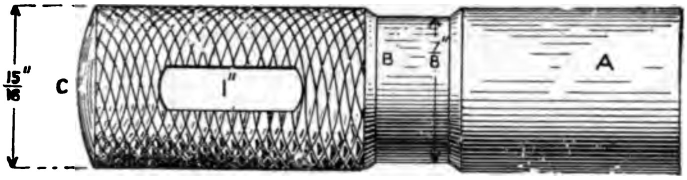


Fig. 3.

The difference between the two characters of measurements described — approximate and precise — may be readily seen in the plug gauge shown in Fig. 3. The gauge end A must be, when ground and lapped, *exactly* 1 inch in diameter, as shown by the stamped size on the handle C. The handle should be $\frac{15}{16}$ inch in diameter and knurled, and the neck $\frac{7}{8}$ inch. While the end marked A is necessarily a *precise* measurement, B and C are approximate, and an error of $\frac{1}{64}$ inch or more on either diameter would not interfere with the accuracy of the gauge. This does not mean that so great an amount of variation from given sizes should ever occur, but the illustration is given to show that the practical workman will never spend an unnecessary amount of time to produce accurate measurements when approximate measurements will do. On the other hand, all care possible should be taken when lapping the gauge end A to size.

Points to be Observed. Keep the working parts of any machine you may be running as clean as possible. Do not allow chips to collect on the shears (Vs) of your lathe. If these become roughed or worn, accurate turning cannot be done. Keep the machine thoroughly oiled, clean the oil holes out occasionally with a piece of wire, in order that the oil may get to the bearings.

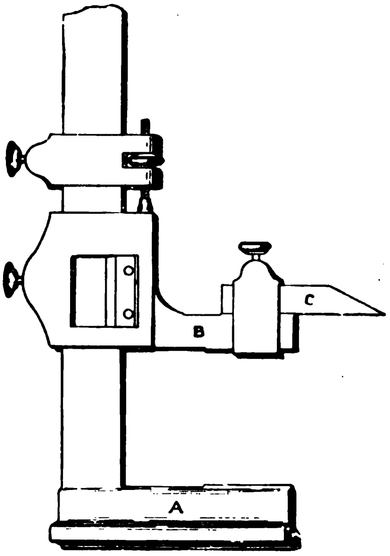


Fig. 4.

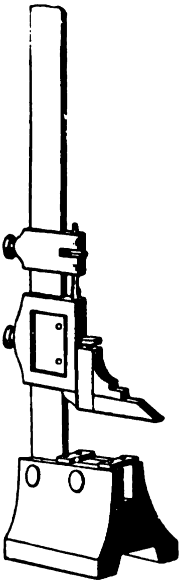


Fig. 5.

Keep the centers of your lathe in good condition, have them to gauge, and be sure the live center runs *true* before taking any finishing cuts. Try the center gauge on your countersink occasionally to see that it maintains its correct shape. Keep your center punch ground to a good point. It is advisable to grind the prick punch used in locating working points in some form of grinder having a chuck or collet to hold the punch while revolving it against the emery wheel; if the point is not perfectly round it will be impossible to indicate a piece of work perfectly on the faceplate of the lathe by means of the center indicator.

Special Tools. A vernier height gauge (Fig. 4) is a very handy tool for making drill jigs, templets and other tools requiring very accurate measurements, and for locating working points, holes or drill bushings. It is used for obtaining the height of projections from a plane surface, or the location of bushings in drill jigs, etc. The fixed jaw A is of sufficient thickness to allow the gauge to stand upright. An extension C attached to the movable jaw B can be used for scribing lines when laying off measurements. In the absence of a height gauge the regular vernier caliper may be made to answer the same purpose by making a base, which may be attached to the fixed jaw as shown in Fig. 5.

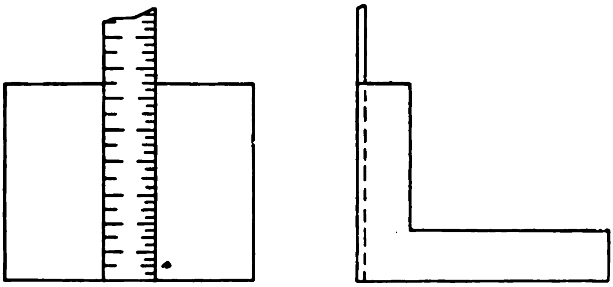


Fig. 6.

A small angle iron having a slot in the upright face to receive a scale for use in connection with a surface gauge when laying off measurements is shown in Fig. 6. The slot should be planed perfectly square with the base of the angle iron.

A pair of accurately machined V blocks is a necessary part of every tool maker's kit. If made of machinery or tool steel they will not need truing as often as if made of cast iron. After roughing out the V's, every surface should be planed square. They should be then clamped against the rail on the planer table by means of finger pieces, having previously trued the edge of the rail. The head of the planer should then be set to the proper angle, usually 45°, and one of the angles finished; the head may now be set over the opposite way and the other angle face planed. The tool used should be ground to give a smooth cut, as it is not advisable to do any finishing with a file or scraper.

A few small gauges of the most common angles will be found very convenient, as they can be used in places not accessible with the ordinary bevel protractor; the angles most commonly used are 60°, 65°, 70° and 80°. The form of gauge is shown in Fig. 7.

If the tool maker should be called on to make punch-press dies, one or more angle gauges, as shown in Fig. 8, will be found very useful. Many die makers use an adjustable square having a narrow blade which passes through the aperture in the die. The amount of clearance given is determined by the judgment of the workman; while this method does very well when practiced by an experienced man, it is rather uncertain when attempted by the novice. To get the proper clearance, the beginner should use the gauge shown in Fig. 8, called (improperly) a die maker's square.

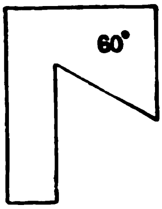


Fig. 7.

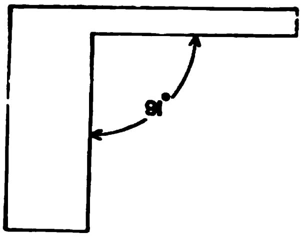


Fig. 8.

The angle depends on the nature of the stock, and the custom in the individual shop; but a set of three gauges, one 91°, one 91½°, and one 92° will meet the requirements, as the clearance is seldom less than 1° or more than 2°. The angle should be stamped on the wide part of the gauge, as shown in Fig. 7. To avoid springing out of shape the stamping should be done before the gauge is finish-filed at any point.

The tool maker should always have at hand a solution of blue vitriol for coloring the surface on which he is to draw lines. To make the solution, dissolve in a two-ounce bottle of water all the blue vitriol crystals the water will take up; to this add one-half teaspoonful of sulphuric acid. This produces a copper-colored surface when put on polished steel free from grease and dirt.

STEEL.

Tool steel is used for tools intended for cutting, pressing, or working metals or other hard materials to shape. In order to successfully work tool steel a knowledge of some of its peculiarities is necessary.

Carbon is the element in tool steel that makes it possible to harden it by heating to a red heat and plunging into a cooling bath. A bar of steel from the rolling mill or forge shop is decarbonized on its outer surface to a considerable depth; consequently this portion will not harden, or if it does the results will be far from satisfactory. For this reason if a tool is to be made having cutting teeth on its outer surface, it is necessary to select stock of somewhat greater diameter than the finish size, so that this decarbonized portion may be removed. About $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch, $\frac{1}{8}$ inch for sizes up to $1\frac{1}{2}$ inches, $\frac{3}{16}$ inch for sizes up to 2 inches, and $\frac{1}{4}$ inch for sizes above 2 inches will usually be sufficient.

Tool steel may be procured in almost any form or quality. It is ordinarily furnished in round, octagonal, square or flat bars. Many tool makers prefer octagonal steel for tools which are to be circular in shape, but experience shows that steel of various shapes of the same make does not differ materially provided the quality and temper are the same.

Cutting tools should be made of high carbon steel if it is to be forged or hardened by skillful operators. If the steel is to be heated by an inexperienced man, it is not safe to select a steel having a high percentage of carbon.

For non-cutting tools, such as mandrels, it is well to select a low carbon steel (one per cent carbon or less), because with this steel there is not as great a tendency to spring when hardening.

Hammered steel is prized more highly than rolled steel by fine tool makers, but authorities do not agree on this point. It is generally conceded, however, that the best tools can be made from forgings if the heating and hammering have been correctly done. The steel should be heated uniformly throughout, and hammered carefully with heavy blows at first. Lighter blows should follow, and, when the piece passes from low red to black, great care is needed to prevent crushing the grain. Steel properly heated and hammered will have a close, fine grain.

Cutting from Bar. It is advisable when cutting a piece of stock from the bar to use a *cutting tool* of some description, such as a saw or cutting-off tool. It is decidedly poor practice to weaken the bar with a cold chisel and then break by a sudden blow or yank. This process so disarranges the particles of steel that they do not assume their proper relations with one another when hardened. If it is necessary to cut the steel with a chisel heat the bar to a *red heat*, as it may then be cut off without injury.

Centering. When centering, care should be taken that the center punch mark is exactly in the center of the piece on each end, so that an equal amount of the decarbonized material will be turned from all parts of the piece (see Fig. 9.) If centered as shown in Fig. 10 the decarbonized portion will be entirely removed at side marked B, and will not be on the side marked A, consequently when the piece is hardened the side marked B will be hard, while the opposite side A will be soft, or at least not as hard as B.

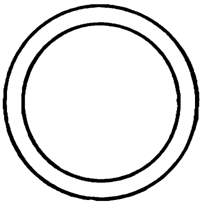


Fig. 9.

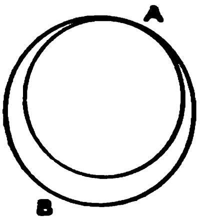


Fig. 10.

Straightening. A piece of tool steel that is to be hardened should *never* be straightened when cold. If it is bent too much to remove all the decarbonized steel when turning to size, it is best (generally speaking) to use a straighter piece of stock. But if the bent piece must be used, heat it to a red heat and straighten. A piece of steel straightened when cold is almost sure to spring when hardened.

ANNEALING.

In order that it may be soft enough to work easily, tool steel must be annealed. It can generally be bought in this condition cheaper than it can be annealed when needed in the factory. Annealing also removes the strains, or the tendency of the steel to crack and spring when hardened. Strains are caused by rolling and hammering in the steel mill or forge shop. In order to remove this tendency to spring, the piece of steel should be machined somewhere near to size, yet leaving sufficient stock to machine all over after the annealing. If it is a piece with a hole n it, such as a milling machine cutter blank, the hole should be drilled somewhat smaller than finish size ($\frac{1}{16}$ inch is the amount generally allowed) and the piece turned in a lathe to remove all the outer surface which contains the marks of the hammer or rolls. The piece is now ready for annealing. To anneal a piece of steel it should be heated to a uniform red heat and allowed to cool slowly. Steel may be annealed by any one of several methods.

Box Annealing. For this method it is necessary to have a furnace large enough to hold an iron box of sufficient size to take the piece to be annealed. To do this work cheaply, enough pieces should be annealed at a time to fill one or more boxes, according to the capacity of the furnace.

The material used in packing the box is wood charcoal, which should be ground or pounded until the particles are about the size of a pea. A layer of charcoal covering the bottom to a depth of one inch is first placed in the box, then a layer of steel. The different pieces should not come within $\frac{1}{2}$ inch of each other nor within 1 inch of the box at any point. The spaces between the pieces are filled with the charcoal, and they are covered to a depth of 1 inch. Another layer of steel may be put in if the box is of sufficient size. When within $1\frac{1}{2}$ inches of the top fill with charcoal, tamp down, put on the cover, and lute around the edges with fireclay, to prevent the direct heat of the fire entering the box.

Test Wires. There should be several $\frac{1}{4}$-inch holes drilled through the cover near the center, and through each of these a piece of $\frac{3}{16}$ inch wire should be placed. The wires should extend to the bottom of the box and project about 1 inch above the top of the cover in order to be readily grasped by the tongs. These wires are intended to be drawn from the box in order to determine when the contents are red hot. The box should be placed in the furnace. After the box has become thoroughly heated, one of the wires may be drawn out by means of a pair of long tongs. If no such tongs are available the legs of ordinary tongs may be lengthened by pieces of gas pipe. Note the time when the wire is red hot the entire length. If not red hot draw another in ten or fifteen minutes, and continue doing so until a wire is drawn that is red the entire length. The work should be timed from the time the box is heated through; this is shown by the wire.

The heat should be maintained a sufficient length of time to insure a uniform heat, which should not be allowed to go above a full red. The length of time the pieces remain in the fire depends somewhat on the size; for steel 2 inches and under, one hour after the box is heated through will do; larger pieces require a longer time. After running for the necessary length of time the heat should be shut off and the boxes allowed to cool slowly; the pieces should be left in the box until cold.

When there are no facilities for annealing by the method described, the piece may be heated to a uniform red and placed on a piece of board in an iron box, having one or two inches of ashes under the board. A second piece of board should be placed on the steel and the box filled with ashes. The pieces of wood will smoulder and keep the steel hot for a long time.

Another common method of annealing tool steel is to heat the piece to a red heat and bury it in ashes or lime. This is likely to give unsatisfactory results unless the ashes or lime are also heated. This can be accomplished by first heating a large piece of iron and burying in the contents of the annealing box. When the steel to be annealed is sufficiently heated the piece of iron may be removed and the piece to be annealed put in its place and thoroughly buried in order that it may take a long time in cooling; it should be allowed to remain in the ashes or lime until cold.

There is another method of annealing practiced in some shops, which answers in an emergency, but it is not to be recommended for general use. This is known as the *water anneal.* The piece of steel should be heated to a *low red,* making sure that the heat is uniform throughout. It should be removed from the fire and held in the air where no draft can strike it until no trace of red can be seen, even if the piece is held in a dark place; it should then be plunged in water, and allowed to remain until cold. Better results may be obtained if plunged in soapy water or oil.

Long pieces which spring when annealed should not be straightened when cold, if they are to be hardened.

HARDENING.

Tool steel may be hardened by heating to a low red heat and plunging in some cooling medium, as water, brine or oil.

Heating. A piece of steel should never be heated any hotter than is necessary to give the desired result. The heat necessary varies with the make of the steel, the amount of carbon it contains, the size and shape of the piece, and the purpose for which it is to be used. Much depends on heating uniformly; a piece of steel should be given a *uniform heat throughout*, the edges and corners should be no hotter than the center, and the interior should be of the same temperature as the surface. If not, the piece is likely to crack in the cooling bath, on account of the uneven changes which take place in the molecular structure. While it is highly important that the steel is heated no hotter than is necessary, yet it is of *much more* importance that it be heated uniformly.

If the piece is heated in an ordinary forge, be sure that the air from the blast does not strike it. For a large piece build a large high fire; have it well heated through before putting in the steel. Use the blast only enough to keep a lively fire; have the steel well buried in the fire in order that the air may not strike it.

Cooling. When the piece is uniformly heated it should be plunged into a suitable bath to give it the proper hardness. It must be worked rapidly up and down, or around in the bath in order to get it away from the steam generated by the red hot steel coming in contact with the liquid, and also that it may constantly come in contact with the cooler parts of the bath. If the piece is long and slender it must be worked up and down; if it is short with teeth on the outer edge, as a milling machine cutter, it should be worked around rapidly in order that all the teeth may be cooled uniformly. If it is flat and has a hole through it whose inner walls must be hard, it should be swung back and forth in order that the bath may pass through the aperture and at the same time strike both faces.

If the tool is not to be hardened all over, and it is necessary to heat it higher than the point where the hardening is to stop, it may be dipped in the bath to a point a trifle higher than we wish it to harden, and then worked up and down a little. If this is not done there will be a line where the piece is expanded at one side and contracted on the other; it is likely to crack at this line, which is called a "water line."

Delicate articles, or those tools having long projections or teeth, should not be dipped in a bath of very cold water or brine; for such work a tepid bath gives better results.

Steel should always be hardened at a heat that leaves the grain *fine* when the piece is broken. This can be determined by hardening and breaking a small piece from the same bar from which the tool to be is made. A *coarse grain* denotes a heat higher than the steel should receive.

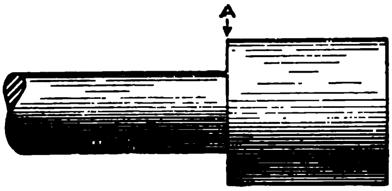
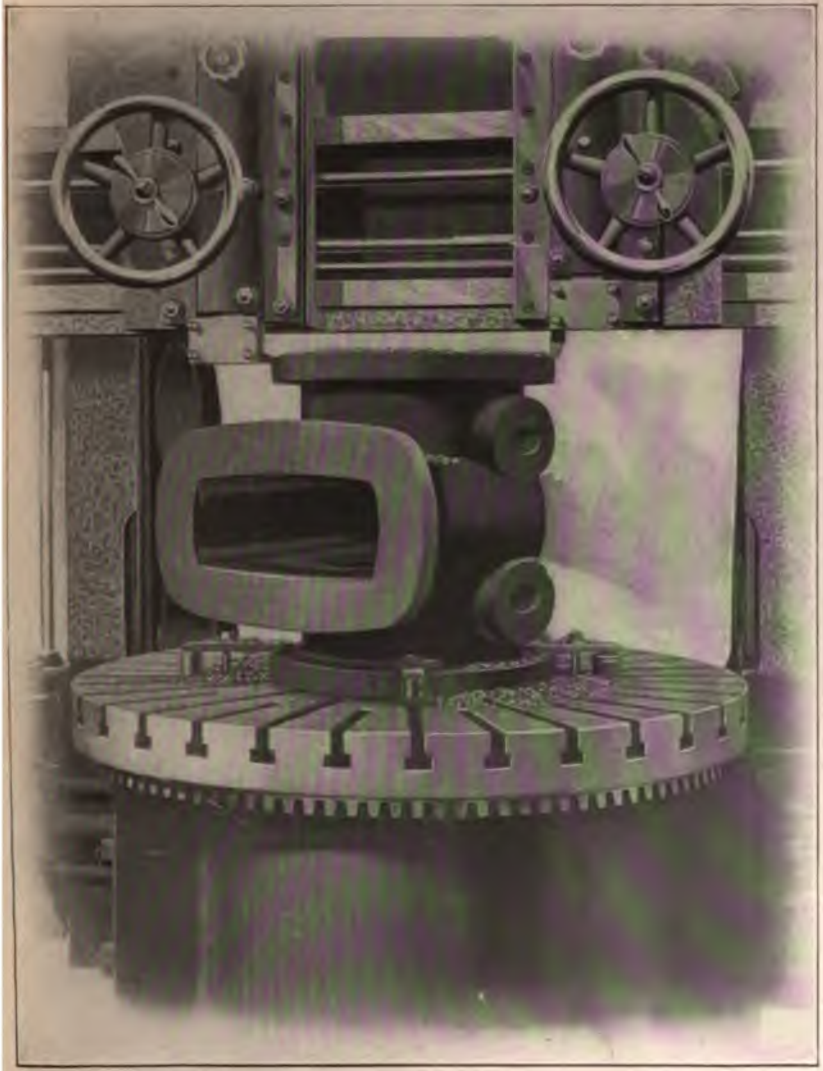


Fig. 11.

It will be found necessary when heating some kinds of steel to put the articles in an iron tube so that air cannot come in contact with them; this is especially true when hardening such tools as taps or formed mills whose outer surfaces cannot be ground, because the oxygen in the air acting on the carbon at the surface of the piece of steel *burns* it, leaving the surface decarbonized. Better results can be obtained with any tool if it is kept from the action of the fire when heating for hardening.

When hardening a piece having a shoulder A, on the outside, as shown in Fig. 11, or inside, as shown in Fig. 12, hardening should not stop at the shoulder, as the unequal strains occasioned by the contraction of the hardened part at the shoulder are likely to cause it to crack at that point. The piece should not be hardened as high as the shoulder, but should it be necessary to do so, it is well to harden a little beyond.

Citric Acid Bath. An excellent bath for hardening small pieces may be made by dissolving one pound of citric acid crystals in one gallon of water. It should be kept tightly closed when not in use or it will evaporate. Small tools heated to a low



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red heat and dipped in this solution harden more uniformly than when immersed in clear water.

Pack Hardening gives excellent results with pieces that cannot be hardened by the methods ordinarily employed without risk of springing or cracking. The article is packed in an iron box with some carbonaceous material, and subjected to the action of heat to allow it to absorb enough carbon to harden in oil. While this method is not generally used, it is very valuable when hardening such pieces as milling machine cutters, blanking dies for punching presses, gauges, and taps where it is necessary that the diameter and pitch are not altered. The carbonaceous material is charred leather, which should be ground or pounded very fine (usually about one-half the size of a pea), and mixed with an equal quantity (volume) of wood charcoal whose granules are of about the same size. These should be thoroughly mixed. An iron box somewhat larger each way than the piece to be hardened should be selected. A layer of the packing material one inch deep should be placed in the bottom of the box and the piece laid on this; the box should then be filled with the packing material and tamped down. Fill the space between the cover and the box with fire clay, thus sealing it so that the gases in the box cannot escape and the direct heat of the fire cannot get into the box.

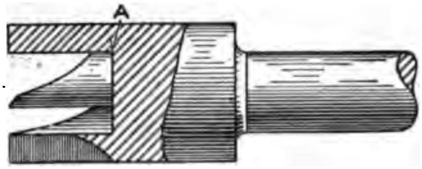

Fig. 12.

It is much more economical to pack a number of pieces at a time, as several may be hardened at the cost of one, and at a saving in packing material. The pieces should be wired with ordinary iron binding wire of a sufficient size to sustain the weight when the wire is red hot. One end of the wire should project over the outside edge of the box, and should be covered with the luting of fire clay. Several holes should be drilled near the center of the cover for test wires, as when annealing. The wires should extend to the bottom of the box. The box may now be heated sufficiently to charge the pieces with carbon. As steel does not commence to absorb carbon until it is red hot, the time is determined by means of the test wires as described under "Annealing." For ordinary tools ½ inch diameter and under, run 1 hour to 1½ hours after it is red hot: pieces from ½ inch to 1 inch diameter, 2 to 2½ hours: pieces from 2 to 3 inches diameter, 2½ to 4 hours. The above must be varied according to the nature of the work.

After remaining in the furnace, the box should be taken out, the cover removed, and the piece taken out by means of the wire attached to it. It should then be immersed in a bath of *raw linseed oil.* The piece should be worked around in the bath until the red has disappeared; it may be then lowered to the bottom of the bath and allowed to remain until cold.

When a piece of steel one inch in diameter or larger is hardened, it should be reheated over the fire immediately on taking out of the bath, in order to avoid cracking, from the strains caused by molecular changes which take place after the outside surface is hardened and unable to yield to the internal strains. Reheating the surface to a temperature of about 212° will accomplish the desired result without materially softening the steel.

TEMPERING.

The hardening of a cutting tool makes it too brittle to stand up well when in use, and consequently it is necessary to soften it somewhat. This is known as "drawing the temper," and is accomplished by reheating to the proper temperature, which is ordinarily determined by the color of the surface of the tool, which must be brightened previous to this operation. As the piece of steel is heated, a light, delicate straw color will appear; then, in order, a deep straw, light brown, darker brown, light purple, dark purple, dark blue, pale blue, blue tinged with green, black. When black, the temper is gone. These colors furnish a guide to the condition of hardened steel.

The following list gives the color denoting the tempers generally used for tools:

Light straw	For lathe and planer tools, scrapers for brass, etc.
Deep straw	For milling cutters, reamers, large taps, etc.
Brown	For twist drills, drifts, flat drills for brass, etc.
Light purple	For augurs, screw slotting saws, etc.
Dark purple	For saws for wood, cold chisels, screwdrivers, etc.

The following table gives the degree of heat corresponding to the different colors mentioned in the previous table.

Light straw	430 degrees F.
Deep straw	460 degrees F.
Brown	500 degrees F.
Light purple	530 degrees F.
Dark purple	550 degrees F.
Dark blue	570 degrees F.
Pale blue	610 degrees F.
Blue tinged with green	630 degrees F.

When work is tempered in large quantities the above method is expensive. Also it is not as reliable as when the articles are heated in a kettle of oil, using a thermometer for indicating the temperature. A piece of perforated sheet metal or wire cloth should be used to keep the articles two or three inches from the bottom of the kettle. A perforated sheet iron pail two inches smaller in diameter than the kettle, resting on a piece of iron, or a frame placed in the bottom will keep the pieces from the sides and bottom of the kettle.

The thermometer should be placed in the kettle outside the pail in order that the bulb may be at the same depth as the lower pieces.

Case Hardening. When an article of wrought iron or machinery steel is to have a hard surface it is treated while red hot with some material which forms a coating or case of steel, which hardens if dipped in water while red hot. Small articles such as nuts, screws, etc., may be case hardened by heating red hot and covering with a thin layer of powdered cyanide of potassium; when the cyanide of potassium melts, the article may be heated red hot again; it is then plunged into water. Care should be exercised when using this substance, as it is *extremely poisonous.*

The above method may be used for hardening a few pieces quickly, but it is not recommended for large quantities of work. When many pieces are to be case hardened at a time, the following method will be found less expensive and much more satisfactory:

Granulated raw bone and granulated charcoal should be mixed in equal quantities, and a layer of this mixture placed in an iron hardening-box to the depth of 1 or 1½ inches. A layer of articles is then placed on this; the pieces should not come within ½ inch of each other, nor within 1 inch of the walls of the box at any point; they should be covered with a layer of the mixture of bone and charcoal to the depth of ½ inch. Successive layers may be placed in the box until it is filled to within 1 inch of the top, when the cover may be put in place and the edges luted with fire clay. The test wires should be used as described for annealing. The heating should be timed from the time the contents of the box are red hot, which can be determined by the test wires. The length of time the work is allowed to run while red hot depends upon the desired depth of the hardened surface; generally carbon will penetrate wrought iron ⅛ inch in twenty-four hours, but as it is rarely necessary to harden deeper than $\frac{1}{32}$ inch, the work may be kept red hot three to four hours. With small pieces, the contents of the hardening-box may be dumped into a tank of running water; if the pieces are large, it is necessary to dip them one at a time in a bath, the same as for tool steel. For extreme toughness, the pieces, if small, may be dumped into a perforated sheet-metal pan and the *packing material sifted out*, after which they may be placed in a bath of oil; if not sifted out, the packing material will stay at the top of the oil and set fire to it. If the pieces are large, they may be dipped one at a time.

Spring Tempering. A piece of steel may be spring tempered by first hardening and then drawing the temper to a degree to which the piece, when bent, will return to its normal shape, when the pressure is removed. This may be accomplished by covering the surface with tallow or some animal oil, and then heating until the oil catches fire from the heat in the piece.

DRILLS.

The forms of drills commonly used in the machine shop are the flat drill, single-lip drill and twist drill.

Flat Drills, intended for use in the engine lathe for chucking, are usually forged to shape in the forge shop. After centering the end, which rests on the tail center of the lathe, the lips are ground to shape and the drill is ready for use. A drill of this description is shown in Fig. 13.

If it is necessary to have the drill cut nearly exact to size, it should be forged somewhat wider than finish size, and the edges turned in the lathe as in Fig. 14. The projection A must be left on the cutting end to provide a center for turning. If the drill is to be ground to size after hardening, the projection must be left on until the grinding has been done, but, ordinarily, this class of drill is not intended to cut exact enough to require grinding.

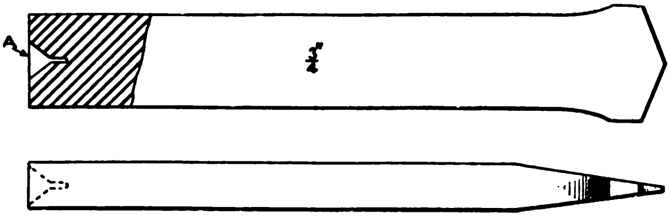

Fig. 13.

If the edges of the drill are not to be ground to size, they should be draw-filed a small amount to avoid binding. The filing should not come within $\frac{1}{64}$ inch of the edge, and should be only a small amount (.003 or .004 inch will be found sufficient); if given too much relief the drill will jump and chatter. The shank should be somewhat smaller ($\frac{1}{32}$ to $\frac{1}{16}$ inch) than the cutting end in order not to touch the sides of a hole drilled deep enough for the shank to enter. The center in the shank end should be large, to insure a good bearing on the tail center of the lathe, as shown at A, Fig. 13.

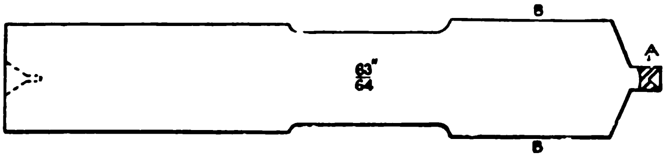

Fig. 14.

When hardening, the drill should be heated a *low red* to a point above the cutting end, preferably about one-half the length of the portion turned smaller than the ends. When dipped in the bath it should be plunged about one inch above the cutting end. To insure good results it should be worked up and down and around in the bath, which may be either water or brine. The temper should be drawn to a brown color.

When a flat drill is intended for use in a drill press, the shank is left round, in order that it may be held in a chuck or collet.

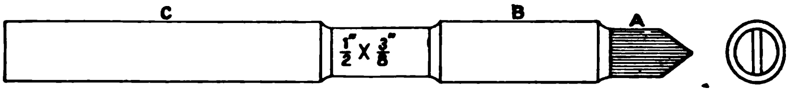

Fig. 15.

Transfer Drill. Another form of flat drill termed a transfer drill, is very useful when a small hole is to be transferred from a larger. The shank C, Fig. 15, may be made of any convenient size; the portion B is of the size of the larger hole, while A is of the size of the hole to be transferred, and is a short *flat* drill.

When making this drill, if a lathe is used having draw-in split chucks, the drill may be made from drill rod, which should be enough larger than finish size to allow B to be turned, to insure its running true with A; the cutting part A may be milled or filed to thickness. The cutting lips are then backed off, and the drill hardened. It should be hardened high enough so that A and B are hard, as the portion A does the cutting, while B, being a running fit in a hole, is likely to rough if it is soft.

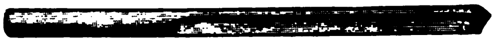

Fig. 16.

To harden it should be heated in a tube and dipped in water or brine, and worked up and down, to avoid soft spots caused by steam keeping the water from the metal, as sometimes happens when a piece has different sizes close together. The cutting portion A should be drawn to a deep straw color; B should be left as hard as possible, to resist wear.

Straightway, or straight fluted drills, have the flutes cut parallel to a plane passing through the axis of the drill, as shown in Fig. 16. They are used in drilling brass, and in drilling iron and steel when the holes break into one another, as shown in Fig. 17.

The smaller sizes may be made of drill rod. After cutting to length, the blank may be put in a chuck in the lathe and the end pointed to the proper cutting angle. When milling the flute, the shank may be held in the chuck on the end of the spiral head spindle. The head should be set at an angle that makes the flute deeper at the cutting end of the drill than at the shank end; this causes an increase of thickness at the shank, thus making the drill stronger than if the flute were of uniform depth throughout. The milling cutter should be of a shape that will make the cutting face of the drill a straight line when the drill is ground to the proper cutting angle. The corner should be somewhat rounded. The general shape of the cutter is shown in Fig. 18.

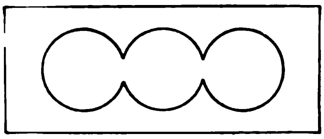
Fig. 17.

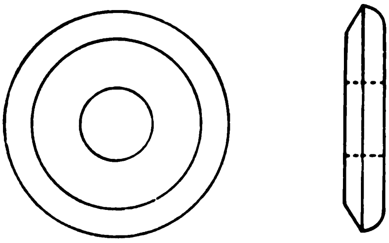
Fig. 18.

Single Lip Drill. For certain classes of work the single lip drill is very useful. Having but one cutting edge its action is similar to that of a boring tool used for inside turning in the engine lathe. The body of the drill being the size of the hole drilled insures its cutting a straight hole, even when used in drilling work partly cut away, or castings having blow-holes or similar imperfections. It does not cut as rapidly as the other forms, consequently is not used where a twist drill would do satisfactory work. Fig. 19 shows a form of single lip drill to be used with a bushing. The steel for this drill should be somewhat larger than finish size, in order that the decarbonized surface may be removed;

the cutting end A and the shank B should be turned .014 to .020 inch larger than finish diameter to allow for grinding after the drill is hardened. The portion C should be turned to finish size and stamped. In order that the drill may be ground to size after it is hardened it will be found necessary to face the end back,

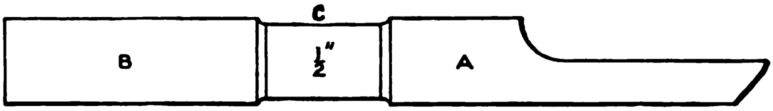

Fig. 19.

leaving the projection containing the center as shown at A in Fig. 20. The cutting end should be milled to exactly one-half the diameter of B. After milling, the face C should be draw-filed until it is flat and smooth. When hardening, the drill should be

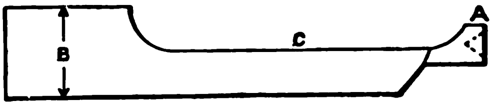

Fig. 20.

slowly heated to a low red, a trifle higher than the portion that is to be cutting size; it should be plunged in a bath of warm water or warm brine in order to avoid as far as possible any tendency to

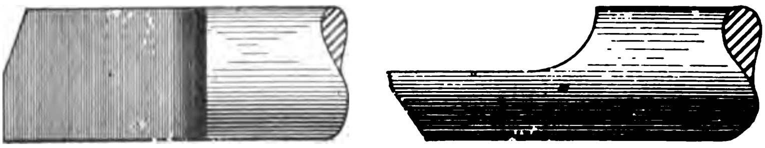

Fig. 21.

springing or cracking in the projection A. The tendency to crack is due to its peculiar shape and the difference in its size and that of the drill. After hardening it may be drawn to a straw color.

When grinding it is advisable to grind the shank first, in order that the grinding machine may be adjusted to grind straight;

after grinding the shank and cutting end to size, the projection A may be ground off, and the cutting end given the required shape, as shown in Fig. 21.

When a single-lip drill is to be used on iron and steel and not upon brass, it may be made to cut more freely by giving the cutting-face rake, as shown in Fig. 22. This may be done by milling the portion A to the proper dimensions, which should be one-half the diameter of the blank. The end and sides of the drill may now be coated with the blue vitriol solution and the desired shape marked out, after which it may be placed in the milling machine vise at the proper angle, and the required amount of rake given by means of small end cutters. After giving the necessary end clearance as shown in the two views of Fig. 22, the drill is ready for hardening.

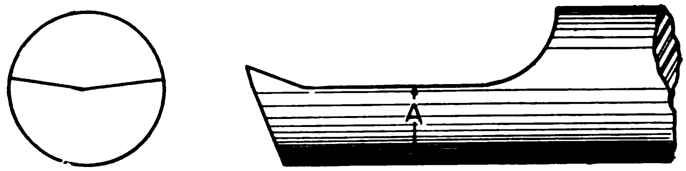

Fig. 22.

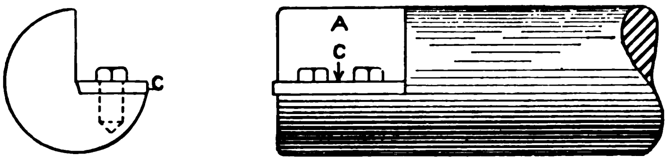

Fig. 23.

In order to adjust a drill of this kind to compensate for wear, it may be made as shown in Fig. 23, in which one-quarter of the circumference is cut away at A and a blade or cutter fastened in position; the top face of the cutter should be radial. To compensate for wear, pieces of paper or thin sheet metal may be inserted under the blade.

The cutter is placed on the arbor directly over the center of the drill, and the bed is set at the angle of spiral, as given in the following table:

Diameter of Drill.	Thickness of Cutter.	Pitch in Inches.	Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	Angle of Spiral.
$\frac{1}{16}$	.06	.67	24	86	24	100	16° 20′
$\frac{1}{8}$	.08	1.12	24	86	40	100	19° 20′
$\frac{3}{16}$	.11	1.67	24	64	32	72	19° 25′
$\frac{1}{4}$	.15	1.94	32	64	28	72	21°
$\frac{5}{16}$	.19	2.92	24	64	56	72	20°
$\frac{3}{8}$	.23	3.24	40	48	28	72	21°
$\frac{7}{16}$	.27	3.89	56	48	24	72	20° 10′
$\frac{1}{2}$	.31	4.17	40	72	48	64	20° 30′
$\frac{9}{16}$	.35	4.86	40	64	56	72	20°
$\frac{5}{8}$	.39	5.33	48	40	32	72	20° 12′
$\frac{11}{16}$	.44	6.12	56	40	28	64	19° 30′
$\frac{3}{4}$	.50	6.48	56	48	40	72	20°
$\frac{13}{16}$	.56	7.29	56	48	40	64	19° 20′
$\frac{7}{8}$	.62	7.62	64	48	32	56	19° 50′
$\frac{15}{16}$	.70	8.33	48	32	40	72	19° 30′
1	.77	8.95	86	48	28	56	19° 20′

The depth of groove in a twist drill diminishes as it approaches the shank, in order to obtain increased strength at the place where the drill is otherwise generally broken. The variation in depth depends on the desired strength or the use of the drill. To obtain the necessary variation of depth, the spindle of the spiral head is elevated somewhat, depending on the length of the flute to be cut; when less than 2 inches in length the angle should be ½ degree: 5 inches and over in length, 1 degree. Usually this will be found satisfactory, but for extremely long drills the elevation must exceed these amounts. The outer end of the drill must be supported, as shown in Fig. 27, and when small should be pressed down firmly until the cutter has passed over the end.

It is somewhat better to use left-handed cutters, so that the cut may begin at the shank end, in order to lessen the tendency of lifting the drill blank from the rest. When large drills are held by the centers the head should be depressed in order to decrease the depth of the groove as it approaches the shank.

nary machine shop; but at times a *special* size or length of drill is needed, or, for some cause, it is necessary to make them.

For the smaller sizes it is best to use commercial drill rod. For drills larger than ½ inch diameter select larger stock and turn it to the desired size. If true holes of the size of the drill are required, it is advisable in the case of drills larger than ½ inch diameter, to turn them .010 to .015 inch larger than finish size, and grind to the required size after hardening. A projection (Fig. 25) containing the center should be left on the cutting end of the drill until after the grinding has been accomplished. After cutting the flutes and grinding the drill, the projection may be ground off and the cutting lips ground to the proper shape, as shown in Fig. 26.

Fig. 25.

When making drills of the smaller sizes from drill rod, the blanks may be cut and pointed to the proper angle on the cutting end; this may be done in the lathe holding the blank in a chuck. The proper angle is 59° from one side of the blank. When milling the flutes of a twist drill on a universal milling machine, the shank of the drill, if straight, may be held in a chuck or collet of the right size, and if very long may be allowed to pass through the spiral head.

Fig. 26.

The following explanation and table are taken from Brown & Sharpe Co.'s book, entitled "Construction and Use of Milling Machines," and are intended for use with the cutters manufactured by them when cutting the flutes in twist drills.

The point C as shown in the enlarged view, Fig. 28, shows where the cutting commences and its increase until it reached a maximum depth at C, where it may be increased or diminished according to the angle employed in the operation; the line of cutter action being represented by I I.

Before backing off, the surface of the smaller drills in particular should be oxidized by heating until it assumes some distinct color to clearly show the action of the mill on the lip of the drill, for, when satisfactory, a uniform streak of oxidized surface, from the front edge of the lip back, is left untouched by the mill, as represented in the cut at E.

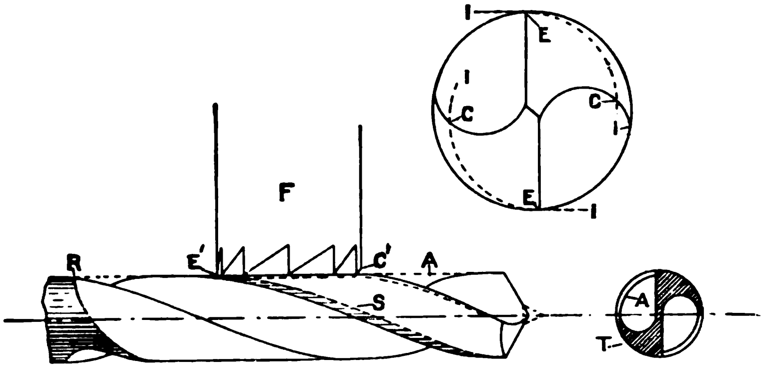

Fig. 28.

If the drills are to be ground without being centered, pointed projections (60°) may be made on the ends as shown in Fig. 28; these projections may be run in female centers in the grinding machine. If tapered back about .003 inch in 6 inches it will be found that the clearance thus obtained will cause them to run much better.

Hardening Twist Drills. Twist drills are hardened by special processes which, generally speaking, are not understood outside the shop where the drills are made. Very good results, however, may be obtained if the drills are heated somewhat and dipped into a solution of the following:

Pulverized charred leather	1 pound
Fine Family Flour	1½ pounds
Fine Table Salt	2 pounds

The charred leather should be ground or pounded until fine enough to pass through a number 45 sieve. The three ingredients are thoroughly mixed while in the dry state, and water is then added *slowly*, to prevent lumps, until the mixture formed has the consistency of ordinary varnish.

After the drill has been dipped in the mixture it should be laid in a warm place to dry; when thoroughly dried the drill may be heated in a tube, or preferably in a crucible of red-hot lead until it is a low red, when it may be plunged in a bath of lukewarm water, or brine; small drills may be dipped in a bath of oil. The drill must not be put in red-hot lead until the coating is thoroughly dried, as the moisture may cause minute particles of lead to fly in all directions, endangering the eyes of the operator. After hardening, the temper may be drawn to a full straw color. If several drills are hardened at a time the temper may be drawn by placing them in a kettle of oil over a fire gauging the amount of heat by a thermometer, as explained under heading of "Drawing Temper."

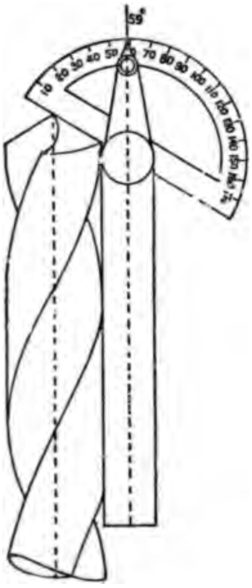

Fig. 29.

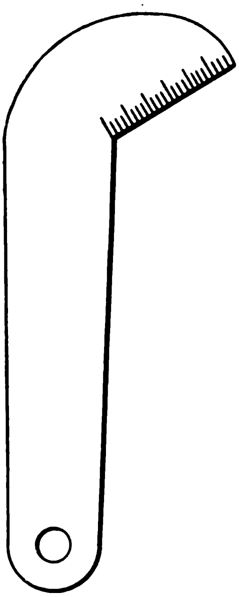

Fig. 30.

Grinding Twist Drills. The cutting edges must make a proper and uniform angle with the longitudinal axis of the drill; they must be equal in length, and the lips of the drill sufficiently backed off for clearance, otherwise they will not cut easily, or they will make a hole *larger* than the size of the drill.

Drills properly made have their cutting edges straight when ground to a *proper* angle, which is 59 degrees, as in Fig. 29. Grinding to an angle less than 59 degrees leaves the lip hooking, which is likely to produce a crooked and irregular hole.

A very satisfactory form of angle gauge for this work is shown in Fig. 30; the graduations on the upper part of gauge show when the lips are ground to an equal length, which is essential in order that the drill shall cut the proper size. As the operator becomes experienced he can gauge the angle and length of lips very accurately by the eye, but until he has the necessary experience it is advisable to use some form of gauge.

REAMERS.

A reamer is a tool that makes a smooth, accurate hole; however, in many cases reamers are used to enlarge a cored hole, or a hole already drilled, without particular reference to the exact size or condition of the hole. Reamers may be classified according to shape as follows: straight reamers, taper reamers, and formed reamers. Reamers are made solid, adjustable, and with inserted blades.

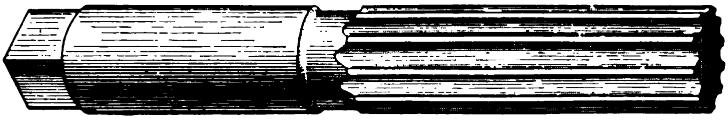

Fig. 31.

Solid reamers (Fig. 31) are so called because the cutting teeth and head are made from one piece; they have no means of adjustment as to size. The cutting teeth of inserted blade reamers are made from separate pieces of steel, and inserted in the head as shown in Fig. 32. The adjustable reamer may be made with inserted teeth, or with cutting teeth solid with the head; but in either case having some means of adjusting the size.

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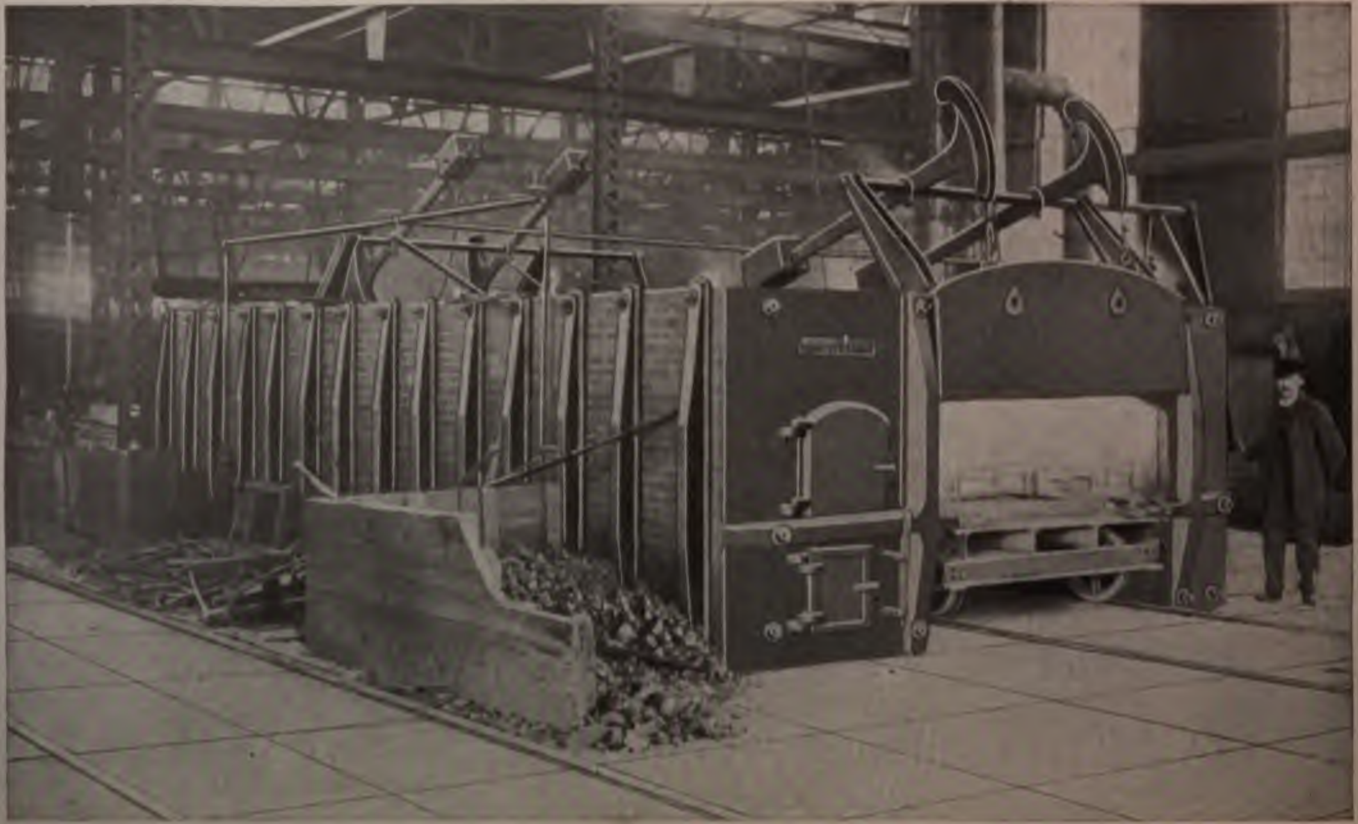

STEEL CASTING ANNEALING FURNACE.

Rockwell Engineering Co.

STRAIGHT REAMERS.

Under this heading the following kinds of reamers are to be found: fluted hand reamers, fluted chucking reamers, rose reamers, single lip reamers, and three and four lipped roughing reamers.

The Fluted Hand Reamer is made straight on the cutting lips, with the exception of a short distance at the end (A Fig. 33) which is slightly tapered in order that the reamer may enter the hole. In making such reamers, use steel from $\frac{3}{32}$ inch to $\frac{1}{8}$ inch above finish size. Turn a chip off the outside surface to a depth of $\frac{1}{32}$ inch and anneal, then turn A and B Fig. 33 to sizes .010 to .015 inch larger than finish size; turn C to finish size, mill the end D square for a wrench. The reamer is now ready to have the flutes cut.

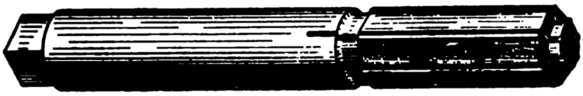

Fig. 32.

Number of Cutting Edges. Fluted reamers designed to remove but a small amount of stock, and intended to cut holes to an accurate size are rarely given less than six flutes.

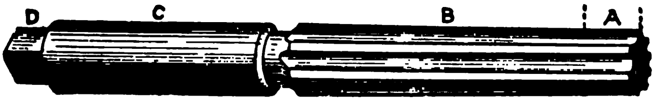

Fig. 33.

The following table gives the number of cutting edges that give satisfaction for solid reamers whose flutes are milled by cutters made to give the proper shape.

TABLE OF CUTTING EDGES FOR REAMERS.

$\frac{1}{8}$" to $\frac{7}{16}$" diameter	6 teeth
$\frac{1}{2}$" to $\frac{11}{16}$" "	6 to 8 "
$\frac{3}{4}$" to 1" "	8 "
1$\frac{1}{16}$" to 1$\frac{1}{2}$" "	10 "
1$\frac{9}{16}$" to 2$\frac{1}{8}$" "	12 "
2$\frac{1}{4}$" to 3" "	14 "

Formerly it was considered necessary to have an odd number of cutting edges; but an even number if unevenly spaced will be as satisfactory. The chief objections to an odd number are the difficulty experienced in calipering unless a ring gauge is used, and the great cost of grinding.

Fig. 34 shows a form of cutter that makes a strong reamer tooth and allows the chips to be removed very readily. These cut the tooth ahead of the center, and should be given a negative rake of about 5°. In general, a reamer will cut more smoothly if the tooth has a slight negative rake, as it then takes a scraping cut.

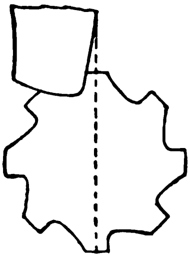

Fig. 34.

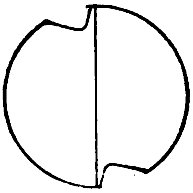

Fig. 35.

With this form of flute, the depth of cut must be so gauged that the land will be about $\frac{1}{5}$ the average distance from one cutting edge to the other; if cut deeper, the teeth will be weak and have a tendency to spring, if not as deep, there will not be room for the removal of the chips. The following table shows the number of cutter (shown in Fig. 34) for any size of reamer.

NUMBERS OF CUTTERS FOR REAMERS.

No. 1	Cutter	cuts	reamers	from	$\frac{1}{8}''$ to $\frac{3}{16}''$	diameter.
No. 2	"	"	"	"	$\frac{1}{4}''$ to $\frac{5}{16}''$	"
No. 3	"	"	"	"	$\frac{3}{8}''$ to $\frac{7}{16}''$	"
No. 4	"	"	"	"	$\frac{1}{2}''$ to $\frac{11}{16}''$	"
No. 5	"	"	"	"	$\frac{3}{4}''$ to $1''$	"
No. 6	"	"	"	"	$1\frac{1}{16}''$ to $1\frac{1}{2}''$	"
No. 7	"	"	"	"	$1\frac{9}{16}''$ to $2\frac{1}{8}''$	"
No. 8	"	"	"	"	$2\frac{1}{4}''$ to $3''$	"

In order that reamers may be calipered readily when grinding — if the teeth have been unevenly spaced — the teeth must be diametrically opposite each other; the unevenness in spacing must be between adjoining teeth. This is done by cutting one tooth, then turning the spiral head of the milling machine half-way round (by giving the index pin twenty revolutions) and then cutting the opposite tooth. When cutting the flutes in pairs, the number of times the cutter must be set for depth of cut is reduced one half. Fig. 35 shows an end view of reamer having the first pair of flutes cut as described.

The irregularity of spacing is obtained by moving the index pin a different number of holes for each adjoining pair of flutes.

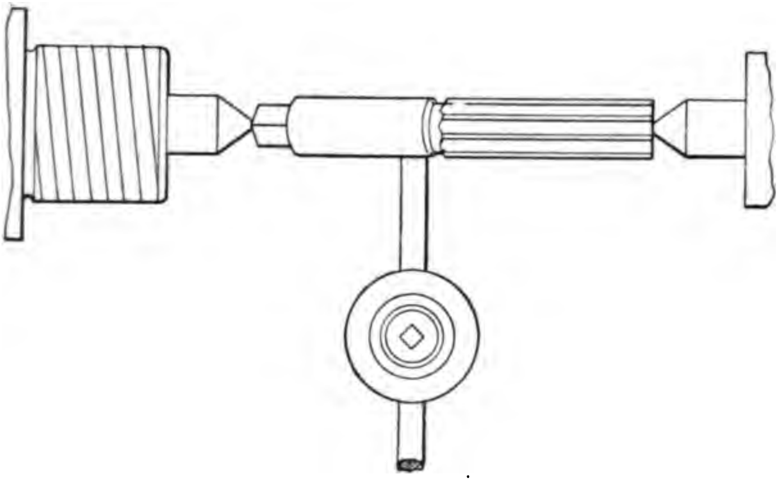

Fig. 36.

This irregularity need not be great; a variation of a few degrees, 2°, 3° or 4° from an angle corresponding to regular spacing is generally considered good practice.

Hardening Reamers. In order that a reamer may not spring when hardened, great care should be exercised in heating. If a muffler furnace is at hand, a uniform heat may be obtained. If heated in a blacksmith's forge the reamer should be placed in a tube to prevent the fire from coming in contact with the steel; it should be turned frequently to insure uniform results. While cooling, the reamer should be held vertically to avoid springing, and should be worked up and down in the bath.

If the reamer is one inch diameter, or larger, it should be removed from the hardening bath when it stops *singing*, and plunged into oil, and allowed to remain until cold. The temper may be drawn to a light straw color.

If reamers are hardened by the "Pack Hardening" process, the danger of springing is greatly reduced.

Straightening Reamers. If a reamer springs while hardening and tempering, it may be straightened by the following method: Place the reamer between the centers of the lathe; fasten a tool, or piece of iron or steel having a square end in the tool post (Fig. 36), placing the square end against the reamer at the point of greatest curvature. The surface of the reamer should be covered with a thin coating of sperm, or lard oil. With a spirit lamp, a plumber's hand torch, or a Bunsen burner, heat the reamer evenly until the oil commences to smoke; pressure may now be applied by means of the cross-feed screw, slowly forcing the reamer over until it is bent a trifle the other way. It should be cooled evenly while in this position. After it is cool the pressure may be relieved and the reamer tested for truth. If it does not run true the operation may be repeated. This method of straightening is equally effective when applied to other classes of work.

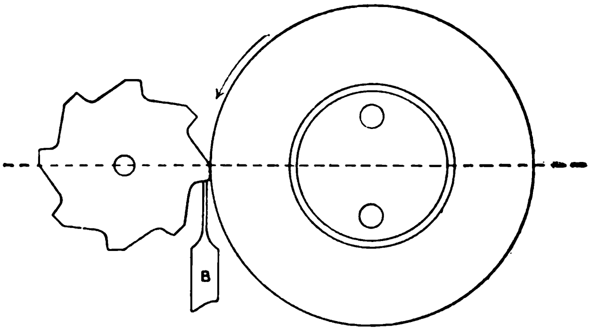

Fig. 37.

The straightening should be done before drawing the temper. When drawing the temper the heat should be applied evenly or the piece will spring from uneven heating.

Before *grinding a reamer* be sure that the centers of the grinding machine are in good shape, then clean the centers of the reamer. The reamer should first be ground to run true. It may be ground to within .001 or .002 inch of finish size; large reamers having the greater amount. In backing off a reamer tooth for clearance use an emery wheel of as large diameter as possible without striking the cutting edge of the next tooth. The correct clearance is given by a finger which can be adjusted. Fig. 37 shows an end view of reamer being ground for clearance together with the finger and emery wheel. The emery wheel should run in the direction indicated by the arrow, in order that the pressure of the wheel will tend to force the reamer tooth down on the finger B. To give clearance, the finger is adjusted so that the cutting edge is below the line of centers as shown. The lower the finger the greater the amount of clearance. Unless a free cutting wheel, free from glaze is used the temper will be drawn, thus rendering the reamer worthless. To avoid softening the teeth, the stock must be removed by a succession of light cuts going way around the reamer each time the adjustment is changed.

A reamer will soon lose its size if the clearance is ground to the edge of the teeth; consequently it is best to grind to within from .01 to .015 inch of the edge, according to the size of the reamer. The reamer is then brought to an edge and to the desired size by oilstoning. To do satisfactory work the stone should be free cutting. Select a stone of medium grade for removing the stock, and use a "fine" stone for finishing the cutting edge. An oilstone should *not* be used dry; keep the face free from glaze. If there are deep depressions or marks in the stone, face it off on a wet grinding machine.

Fluted Chucking Reamers. The same general instructions given for making fluted-hand reamers, can be applied to this form; except that the shank may be finished to size before the reamer is hardened, unless the shank is to fit a collet or be held in a chuck.

The regular jobbing reamer used in the lathe is shown in Fig. 38; the form for the chucking lathe or drill press, where the shank is held in a collet or chuck is shown Fig. 39. When making this style of reamer, B may be left .010 to .015 inch above size to allow for grinding. The portion C may be finished to size and the dimension of the cutting part of the reamer stamped on it as shown; if the reamer is made for special work and is to be used on no other, the name of the piece, or operation it is intended for should also be stamped.

On account of the uncertainty of a reamer cutting exactly to size when used in a lathe, chucking reamers are frequently made somewhat under size. Standard *hand* reamers are used for finishing. The amount of stock left for the hand reamer varies: some tool makers consider .005 inch the proper amount for all reamers up to 3 inches in diameter; while others think that for 1 inch or less diameter .004 inch is right; and for sizes from $1\frac{1}{16}$ inches to 2 inches, .007 inch should be allowed. For reamers larger than 2-inch diameter an allowance of .010 inch should be made. The exact amount necessary for finishing with hand reamers depends on the nature of the work and the stock operated on. Fluted chucking reamers are made with either straight or spiral flutes.

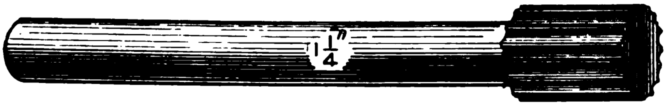

Fig. 39.

When a reamer is used in a screw machine or turret lathe, on work where accuracy and straightness of hole is essential, it should be held in some form of special holder, which allows it to properly locate itself as to alignment. Such holders will be described later under the heading "Reamer Holders."

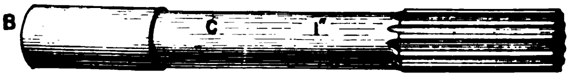

Fig. 39.

Rose Reamers. This form of reamer has its cutting edges only on the end as shown in Fig. 40, the grooves being cut the entire length of body to reduce the amount of frictional-bearing surface and to furnish a channel to conduct the lubricant to the cutting lips. In case there are blow holes or other imperfections in the material being operated on, this reamer will cut a more nearly parallel hole than the fluted chucking reamer.

Fig. 40 shows the ordinary form of rose chucking reamer. The shank B is turned to finish size; in case it is to fit a holder it is left slightly larger and turned or ground to size after hardening. The body A is turned .015 to .020 inch above finish size, the flutes cut, the size stamped as shown, and the reamer hardened a little above the body. It is customary when grinding a rose reamer to make it a trifle smaller on the end of body next to the shank; a taper of $\frac{1}{4000}$ inch in the length of the cutting part gives good results.

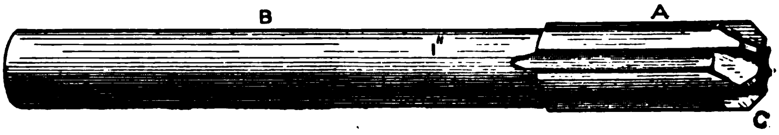

Fig. 40.

Small rose reamers can be made of drill rod, which runs very true to size, if ordered by the decimal equivalent rather than by the drill gauge number, or in terms of common fractions. For instance, if drill rod is wanted of a size corresponding to No. 1 Browne & Sharpe drill gauge, the wire will come much more accurate if ordered .228 inch diameter rather than by the gauge.

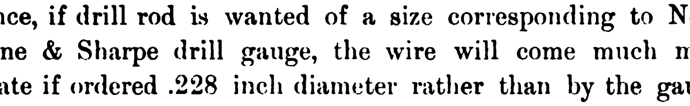

Fig 41.

The wire may be sawed to length, put in lathe chuck, and cornered for the cutting lips. When making small reamers that are not to be ground to size after hardening, it is advisable to neck them down back of the cutting edge, as shown in Fig. 41. The drill rod often swells or expands at a point where the hardening ends, and by necking down and hardening into the necking this difficulty is overcome.

Small rose reamers may be given three cutting edges. The flutes may be filed with a three-square or a round-edge file. If a three-square file is used, a groove of the form shown in Fig. 41 may be made. This has a tendency to push the chips ahead when cutting, while a groove filed with a round-edge file, if it be of a spiral form, will draw the chips back into the flute, provided it is a right-hand helix, as shown in Fig. 42.

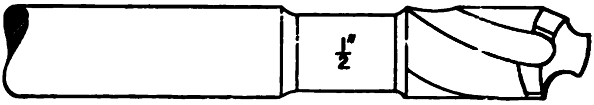

Fig. 43.

Rose reamers intended for reaming holes of exact size must be ground to correct dimensions after hardening, but small reamers intended for reaming holes where *exactness* of size is not essential may be made to size before hardening, and the cutting edges backed off with a file for clearance. If reamers are ground on the circumference for size, the lips or cutting edges should be given clearance by grinding. After grinding, the corners of the cutting edges next to the body of the reamer, as shown at C, Fig. 40, should be rounded by oilstoning.

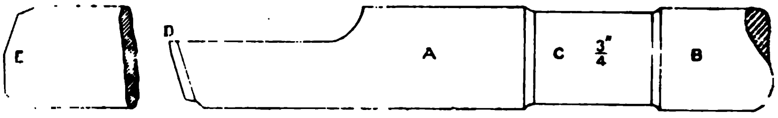

Fig. 43.

A Single Lip Reamer is very useful for reaming a *straight* hole. When the nature of the hole or the condition of the stock would cause the ordinary forms to *run*, the single lip reamer will cut a straight hole if started right. Having but one cutting lip, its action is similar to a boring tool used for internal turning in the lathe, and as a large proportion of the body of the reamer acts as a guide, it must cut a straight hole. Fig. 43 shows two views of this form of reamer.

Steel for this reamer should be sufficiently large to allow the decarbonized surface to be entirely removed. After a roughing chip has been taken,— leaving the piece about $\frac{1}{16}$ inch above finish size,— the stock should be annealed, after which the portions A and B should be turned to a size that allows for grinding. C may be finished to dimensions given, and the size of the reamer stamped as shown.

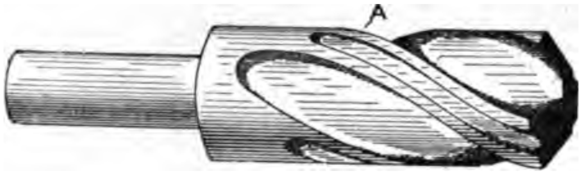

Fig. 44.

The reamer is now ready for milling. This should be done with the reamer in the centers in the milling machine, using a shank mill or a small milling cutter on an arbor. The depth of the cut should be about one-third the diameter of the reamer; for large reamers it may be somewhat deeper. After milling, the face may be smoothed with a fine file, and the end and cutting lip backed off for clearance, as shown in Fig. 43 at D and E.

When hardening, the end A should be heated to a low red and dipped in the bath about one-half an inch on the necked portion C. The temper may be drawn to a light straw. A and B are now ready for grinding. If the grinder has no provision for water to run on the work, care should be used not to heat the reamer, as it is likely to spring.

Three and Four Lipped Roughing Reamers are used to advantage in chucking machines for enlarging cored holes, or holes that have been drilled smaller than the required size. This is often done in making large holes in solid stock, as most manufacturers consider it more economical to use a smaller drill and a [illegible] size for the final [illegible].

[illegible] the various ream- [illegible] of cutting [illegible] hold the chips. [illegible] feed oil to [illegible]. [illegible] is the [illegible] straight and the [illegible] used in sizing the

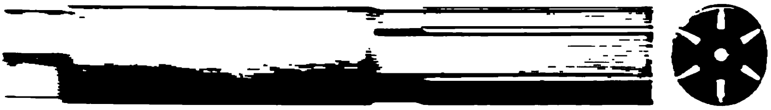

Fig. 47.

[illegible] roughing reamer $\frac{1}{64}$ inch [illegible] rough usage, great [illegible]. While satisfactory results [illegible] plunging in a bath of [illegible], the tools will do [illegible] the process [illegible]

Inserted Blade Reamers. [illegible] A [illegible] end than at the [illegible] at the bottom [illegible] depressing the spiral head [illegible] the slots with a [illegible] the slot wanted, then turning the spiral head [illegible] the desired angle on one side of [illegible] as shown at A in Fig. 48. The object in making

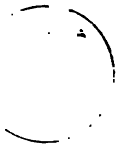

Fig. 48.

the slot deeper at the front end is that the blades, as they become dulled (and consequently cut small), may be driven farther into the body. As the slot is shallower, the blade is forced out as it advances, thus increasing its diameter; it may then be sharpened by grinding to size. The side of the slot is cut at an angle to hold the blade solidly and prevent any tendency it might have to draw away from its seating when the reamer is cutting. The body of the reamer is not hardened; the blades are machined to size, hardened, driven into place and ground to size. If the

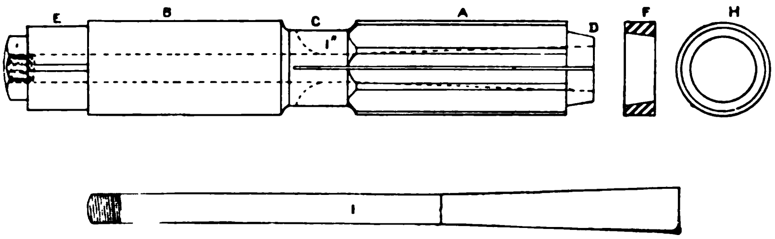

Fig. 47.

reamer is of the form known as *fluted reamer*, the teeth may be backed off for clearance as already described.

Adjustable Reamers are made of a form that allows them to be adjusted to a varying size of parts of machines where interchangeability is not essential. Fig. 47 shows the cheapest form of adjustable reamer; this form is sometimes objected to because it does not expand or contract uniformly its entire length; for ordinary work, however, it is very satisfactory, if used for a limited range of sizes.

Stock should be selected at least $\frac{3}{32}$ inch larger than finish size. After carefully centering and squaring the ends, a chip should be turned the entire length of the piece. It should then be drilled, and the taper hole reamed for the expansion plug. When drilling the outer end, the blank should run in the steady rest; the hole in the *shank* end should be drilled to the proper depth with a drill $\frac{1}{32}$ inch *larger* than the straight stem of the expansion plug. The end should be chamfered to a 60° angle to run on the lathe center when turning and grinding. The piece may be reversed and the opposite end drilled and reamed with a taper reamer; this end should be chamfered also to a 60° angle. Fig. 48 shows a sectional view of the blank drilled and reamed, and the ends of the hole beveled.

The reamer may now be turned .020 to .025 inch above finish sizes on A and B, while C and D may be turned to finish sizes, and the size stamped at C. The end E may be milled square for a wrench, the grooves milled and the reamer split, in order that the size may be altered with the expansion plug.

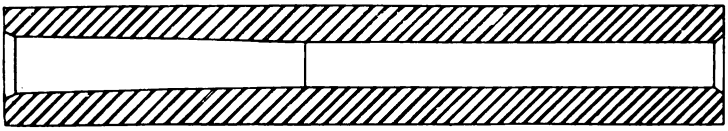

Fig. 48.

When splitting the reamer, a metal slitting saw of the required thickness (usually $\frac{1}{16}$ inch) should be used. The saw cut should not extend to the end of the reamer, but a small portion should be left solid to prevent the reamer from springing when hardening. The circular saw leaves a cut at the end of the shape shown in Fig. 49, which would be extremely difficult to part after hardening. In order that the thin partition of stock may be easily severed with an emery wheel, the slot may be finished, as shown in Fig. 50, with a hand hack saw.

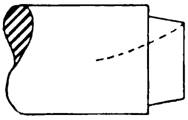

Fig. 49.

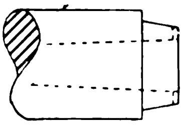

Fig. 50.

The expansion rod I, Fig. 47, should be turned to fit the taper in the reamer, the straight end should be $\frac{1}{32}$ inch smaller than the hole running through the reamer, and should be threaded on the end for a nut to be used in drawing the rod into the reamer. The collar shown at F and H should have a taper hole fitted to the tapered end of the reamer. The outside diameter of collar should be a trifle smaller than the hole to be reamed; this collar, when forced onto the end of the reamer, holds it in place. In order to increase the size of the reamer, the collar may be driven back a trifle and the rod drawn in by means of the nut.

After the reamer is hardened and tempered, the thin partitions left at the ends of the slots may be ground away with a beveled emery wheel, the rod inserted, the collar forced on the end, the reamer ground to size, and the teeth backed off for clearance.

TAPER REAMERS.

If a taper reamer is intended for finishing a hole, the same general instructions may be followed as for *fluted hand reamers*, except that instead of being straight, the body, or cutting part, is tapered.

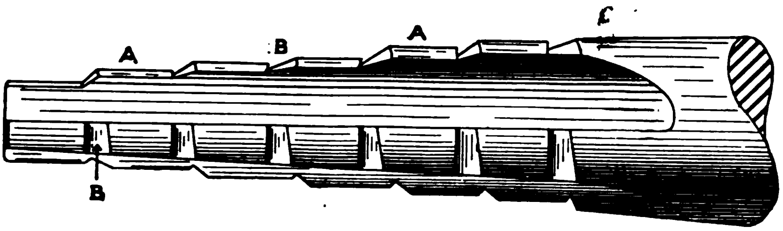

Fig. 51.

Roughing taper reamers are frequently made in the form of a stepped reamer, or it might be called a multiple counterbore, since each step acts as a pilot for the next larger step, as shown in Fig. 51. The steps A are turned straight, each one correspondingly larger than the preceding. The cutting is done at the end of the step B, which must be given clearance; this is ordinarily done with a file. The reamer may be given four cutting edges; these should be cut with a milling cutter intended for milling the flutes of reamers. The number of the cutter selected will depend on the form and amount of taper of the reamers. It is advisable to neck down into the reamer $\frac{1}{32}$ inch at the end of each step; this may be done with a round nose tool, or a cutting-off tool having its corners slightly rounded. The necking facilitates the filing of the cutting edges, and also allows the emery wheel to traverse the entire length of each step when grinding to size after hardening.

Roughing reamers are sometimes made of the form shown in Fig. 52. The left-hand thread cut the entire length of the cutting portion breaks the chips into short lengths, and greatly increases the cutting qualities. After turning the tapered part to a size that allows for grinding, the lathe may be geared to cut a four-pitch thread. The threading tool should be about $\frac{1}{16}$ inch thick at the cutting point, and have sufficient clearance to prevent the heel dragging when the tool is cutting. The corners should be slightly rounded in order to reduce the tendency of cracking when the reamer is hardened. The thread should be cut to a depth of from $\frac{1}{64}$ to $\frac{1}{32}$ inch. After threading, the flutes may be cut, the reamer hardened, and the temper drawn to a light straw.

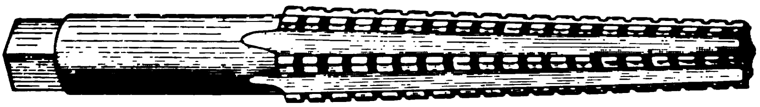

Fig. 52.

When grinding a *taper reamer* the proper clearance is given to the tooth back for a distance of $\frac{3}{64}$ inch from the cutting edge, the balance of the tooth is given a greater amount of clearance, as shown in Fig. 53.

Shell Reamers. As a matter of economy, the larger sizes of reamers are sometimes made in the form of shell reamers, as shown in Figs. 54 and 55. As several reamers may be used on the same arbor, there is quite a saving in cost of material.

The following table gives the size and length of shell reamers from one inch to three inch diameter, together with the size of holes, and width and depth of tongue slot.

			Tongue Slot.	
Diameter.	Length.	Size of Hole.	Width.	Depth.
$1''$ to $1\frac{1}{4}''$	$2\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{4}''$	$\frac{1}{4}''$
$1\frac{5}{16}''$ to $1\frac{5}{8}''$	$3''$	$\frac{3}{4}''$	$\frac{5}{16}''$	$\frac{5}{16}''$
$1\frac{11}{16}''$ to $2''$	$3\frac{1}{2}''$	$1''$	$\frac{3}{8}''$	$\frac{5}{16}''$
$2\frac{1}{16}''$ to $2\frac{1}{2}''$	$3\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{2}''$	$\frac{3}{8}''$

After drilling a hole $\frac{1}{16}$ inch smaller than finish size, the blank should be placed on a mandrel and a heavy chip taken to remove all the original surface. It should then be annealed.

After annealing it may be placed in a chuck on the lathe and the hole bored .005 inch smaller than finish size. After putting on a mandrel, the ends should be faced to length and the outside diameter turned, leaving .010 to .015 inch on the cutting part for grinding. The balance of reamer should be turned to size. If it is to be a *rose reamer* the edge should be chamferred the proper amount.

The reamer should be held in a chuck on the spiral head spindle in the milling machine, and the tongue slot cut. In order to get the slot central with the outside of the reamer, a cutter somewhat narrower than the desired slot should be used, which should be set as centrally as possible by measurement, a cut taken, the spiral head turned one-half way round and another cut taken; the width of the slot should be measured, and the saddle of the machine moved by means of the graduated adjusting screw one-half the amount necessary to make the slot of the right width. The reamer may now be placed on a mandrel between centers on the milling machine, and the grooves cut.

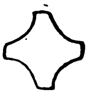
Fig. 53.

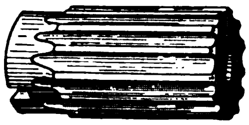
Fig. 54.

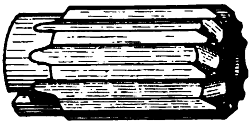
Fig. 55.

The reamer should be heated for hardening in some receptacle in order that the fire may not come in direct contact with it; when it reaches a *low uniform* red heat it may be placed on a wire bent in the form of a hook, and plunged in the bath; it should be worked up and down rapidly until all trace of red has disappeared. When cold it may be heated to prevent cracking from internal strains; if it is to be a rose reamer it may be left *dead* hard, if a fluted reamer the temper should be drawn to a straw color. The hole should be ground to fit the shank on which it is to be used, or a plug gauge, if there is one for the purpose. The reamer may then be placed on a mandrel and ground according to directions given for grinding reamers.

The holes in *shell reamers* are sometimes made tapering — the end of the arbor being made of a corresponding taper — to avoid the necessity of grinding the holes, as any slight change in the size resulting from hardening would be compensated for by the taper hole.

Arbors for Shell Reamers are made as shown in Fig. 56. The shank B and end A to receive the reamer, are made in one piece. The collar C having two tongues to engage in the slots in the reamer, is made of tool steel; the hole is made of a size that allows it to slide over A. When in position a hole is drilled through both collar and arbor and the pin D driven in. When making the collar the hole is drilled and reamed: it is placed on a mandrel, the ends faced to length, and the collar turned to proper diameter. It is then removed from the mandrel and the tongues milled. While doing this the collar is held in the chuck on the spindle of the spiral head and a side milling cutter is used. One side is milled, the spiral head spindle turned one-half revolution, and the opposite side milled; the thickness is measured and the saddle moved enough to bring the tongues to the required thickness when the finish cut is taken on each side. After putting on an arbor and drilling the pin hole, the collar may be removed and spring tempered. It may now be placed on the arbor and the pin driven in place.

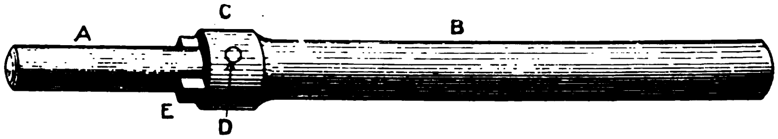

Fig. 56.

When the hollow mill is made with a taper hole, the arbor is made with the end A of a corresponding taper. Otherwise the construction would be the same as for hollow mills having straight holes.

Formed Reamers are used for holes of an irregular shape, or rather of a shape neither straight nor tapering. They are used

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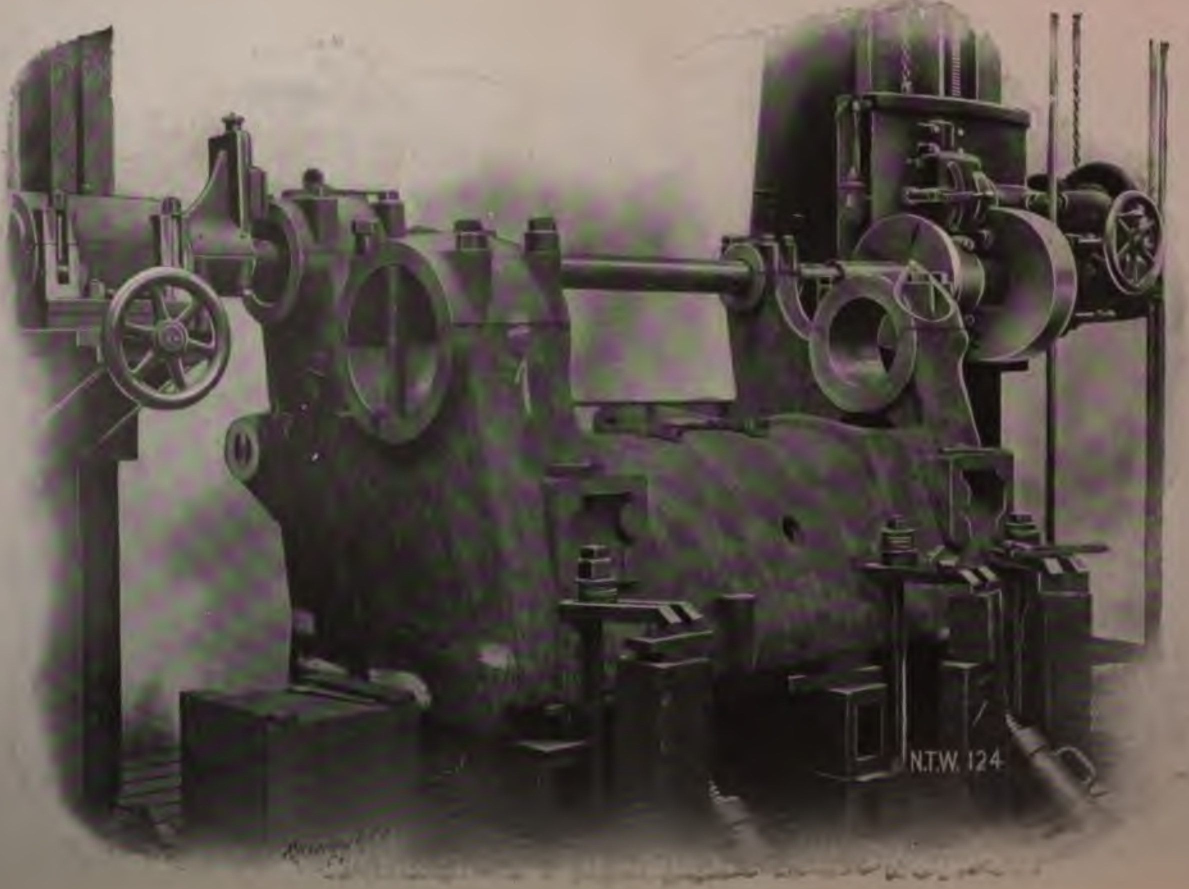
ASTOR, LENOX AND
TILDEN FOUNDATIONS



BORING AND FACING HEADSTOCK OF LATHE.

Niles-Bement-Pond Co.

chiefly by gun makers in reaming the end of the gun barrel for the shell, and are termed, when used for this class of work, *chambering reamers.*

It is essential when making this class of reamer, that the stock be rough turned a little above finish size and then annealed. Reamers of this form are accurate as to size and shape, consequently it is customary to use a gauge. This is generally a piece of steel having a hole of the proper form reamed in it, after which the stock is cut away on one side, leaving a trifle more than one-half of the hole as shown in Fig. 57.

To make the reamer blank fit the gauge the operator must understand the use of hand turning tools, as most shapes must be made with these tools. The teeth must be cut with a milling cutter of small diameter following the different shapes of the reamer in order to have the top of the land of as uniform a width as possible. After cutting, the teeth may be backed off for clearance with a file, taking care not to remove any stock at the cutting edge.

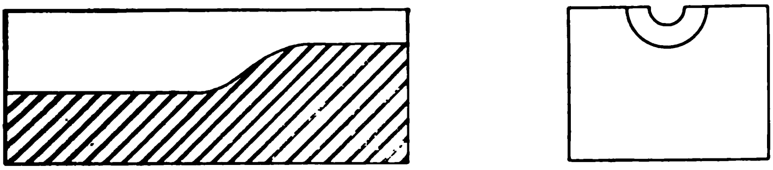


Fig. 57.

When hardening, heat very carefully in a tube until the reamer is of a *low* uniform red heat; it should then be plunged in a bath of lukewarm brine. It may be brightened and the temper drawn to a light straw. After hardening it should be tried in the gauge, and any high spots removed by oilstoning.

If a large number of reamers of one form are to be made, the grinding machine may be rigged with a form which makes it possible to grind many of the shapes in common use, but some shapes will be found quite impracticable to grind, consequently the above method of fitting before hardening must be adopted. Excellent results are obtained by hardening by the "Pack Hardening" process.

Reamer Holders. On account of the uncertainty of exact alignment of every part of a screw machine or turret lathe, it is desirable to use a holder for the reamer that allows it to properly align itself. The form of holder shown in Fig. 58 is in common use and gives excellent results. It consists of the body A which has a hole drilled and reamed its entire length; the hole must be somewhat larger than the shank of the reamer, $\frac{1}{16}$ inch being considered sufficient. The center B of tool steel should be (after hardening) .010 to .015 inch larger than the hole in the holder; the point should be ground to a 60° angle, and the straight part ground to a forcing fit in the holder. After being forced to position a hole may be drilled through the holder and center, and the pin C driven in to keep the center from being pressed back by the reamer when in operation. A pin should be put through the holder at D; a hole $\frac{1}{16}$ inch larger than the pin should be put through the reamer shank at this point. This pin is simply to prevent the reamer from turning when it comes in contact with the work. The coil springs E E hold the reamer in position to enter the hole, and the proper tension is given by means of the screws F F.

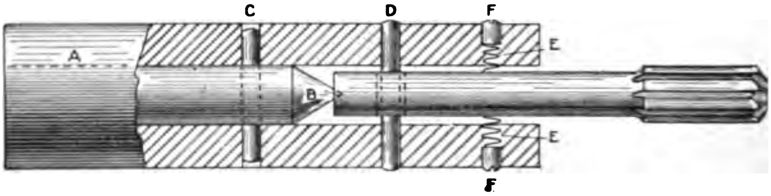


Fig. 58.

ARBORS.

Mandrels. The ordinary taper arbor, known as the mandrel, is in common use in most machine shops. Up to and including $1\frac{1}{2}$ inches diameter, mandrels are made of tool steel, hardened all over and ground to size. Some tool makers advocate making all mandrels up to 4 inches diameter in this way; others prefer hardening the ends B B (Fig. 59), leaving the center A soft, while others maintain that for mandrels above $1\frac{1}{2}$ inches diameter, machinery steel is most satisfactory if thoroughly case hardened.

When making mandrels of tool steel that are to be hardened the entire length, it is not necessary to use the best quality of steel, as a lower grade may be used if it will harden well. Select stock somewhat larger than finish diameter, say $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch; $\frac{1}{8}$ inch for sizes up to 1 inch; $\frac{3}{16}$ inch for sizes up to $1\frac{1}{2}$ inches, and $\frac{1}{4}$ inch for sizes above. Take a chip off the outside sufficiently heavy to remove all scale, yet leaving $\frac{1}{32}$ inch for a finish cut on sizes up to $\frac{1}{2}$ inch and correspondingly more for the larger sizes. It should now be annealed, preferably in the annealing box. The ends should be countersunk deeper in mandrels than in tools where the centers are not used after they are completed, in order that the centers may not be mutilated when driven in or out of the work. The centers should either have an extra countersink, as at A in Fig. 60, or else the cut should be recessed as at B in Fig. 61.

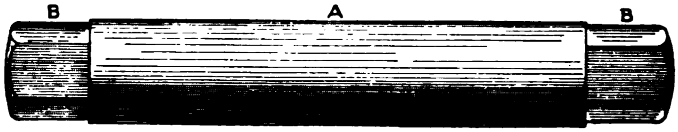


Fig. 59.

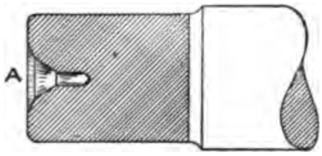


Fig. 60.

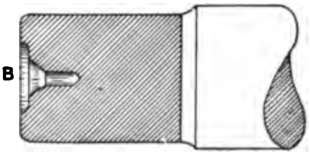


Fig. 61.

The ends B B, Fig. 59, should be turned to size, the corners slightly rounded, and the flat spots for the dog screw milled or planed. The body of the mandrel should be turned somewhat larger than finish size; those smaller than $\frac{1}{2}$ inch should have an allowance of .015 inch; from $\frac{1}{2}$ to 1 inch an allowance of .020 to .025 inch; over 1 inch an allowance of .025 to .030. As the length of mandrels larger than 2 inches diameter does not increase in proportion with the diameter, the amount given will generally be sufficient if proper care is used when hardening. The size should be stamped on the end next to the large end of body.

Before hardening, the centers should be re-countersunk to true them; for this operation it is best to use a special countersink having an angle of 59° instead of the regular 60° tool, as it facilitates the lapping of the centers to a 60° angle after hardening, due to the unequal amount of grinding caused by the shape of the countersinking.

If a blacksmith's forge must be used when heating the mandrel for hardening, the fire should be large enough to heat the piece evenly; it is advisable to heat it in a tube. More uniform results can be obtained from a muffler furnace than in the open fire. In either case the piece should be turned frequently, to insure an even heat. To dip in the bath, a pair of tongs of the shape shown in Fig. 62 should be used, so that the bath may come in contact with both centers. The tongs should grapple the mandrel at the large end, in order that the small end may be harder; it should be worked up and down rapidly in the bath to insure uniform results. A bath of brine will be found very satisfactory for this work.

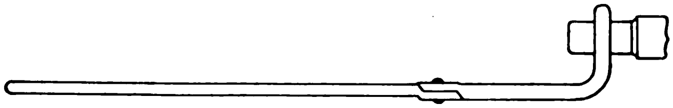


Fig. 52.

A mandrel larger than 1 inch diameter should be removed from the bath as soon as it ceases *singing*, and held in a tank of oil until cold. The ends should be brightened and drawn to a deep straw color, in order to toughen them so that they will not break or chip off when driven. Mandrels smaller than $\frac{3}{4}$ inch should have the temper drawn to a light straw color the entire length of body.

After hardening, the body of the mandrel should be cleaned with a coarse emery cloth, to remove the scale or grease which would glaze the emery wheel. It should then be tested between centers to see if it has sprung more than will grind out before it reaches the proper size.

The centers should now be lapped, to insure proper shape and alignment. The lap may be a piece of copper of the proper shape (60°) charged with diamond dust or emery. After lapping, the centers should be thoroughly cleaned with benzine. (When using benzine do not allow it to get near a flame of any kind.)

Examine very carefully the condition of the centers of the grinder, as the truth of the mandrel depends in a great measure on their condition. A mandrel may be ground in a lathe having a grinding attachment or in any universal grinder. Better results can be obtained, however, if ground in some form of grinder having a stream of water to keep the work from heating, as heat is likely to spring the piece, especially if it does not run true, thus making the grinding heavier on one side than the other. If a dry grinder must be used, do not force the grinding fast enough to heat the piece. The mandrel should be ground to within about .005 inch of size with a coarse wheel free from glaze, and then finished with a fine wheel.

The amount of taper varies: some manufacturers prefer .0005 inch taper per inch, while others make them of .001 inch taper for every inch of length, claiming that if a piece having a long hole is to be held on *any* taper mandrel it will not fit at the end nearest the small end of mandrel, consequently the turned surface will not be true with the hole; also that for such work a mandrel should be made for the job having a body nearly or quite straight. They claim that the mandrel should be made to taper .001 inch for every inch of length, in order that it may be adapted to a greater range of work.

Mandrels with Hardened Ends. When making a mandrel whose ends are to be hard and body soft, follow the instructions given for hardened mandrels, except that a larger amount of stock should be left on the body. The ends should be hardened for a distance that insures the *centers* being hard; this can be accomplished by heating one end at a time to a red heat, and inverting under a faucet of running water. As the center is uppermost, the water can readily enter it, forcing the steam away. After

[illegible]

[illegible]

a bath having a jet of water coming up from the bottom to force the steam away from the work, to avoid soft spots. It is not necessary to draw the temper, as the hardening does not extend far below the surface.

Expanding Mandrels. There are several forms of expanding mandrels in common use. One form has a sleeve with a taper hole fitting on a mandrel that has a corresponding taper; the sleeve is split to allow it to expand as it is forced on the mandrel.

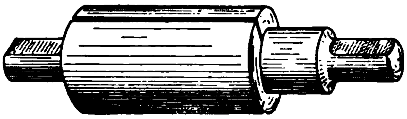


Fig. 63.

It is not advisable to give the mandrel very much taper, because a heavy cut with the pressure toward the small end would crowd the sleeve toward that end, thereby releasing the work. Ordinarily a taper of $\frac{1}{2}$ inch to the foot will give good results.

It is obvious that the range of adjustment for a sleeve as described is small, but sleeves of different diameters may be fitted to the same mandrel, the thickness of wall being increased to give the desired size. The diameter of the sleeve should be such that the work may enter without forcing, the tightening being accomplished by forcing or driving the sleeve toward the large end of the mandrel.

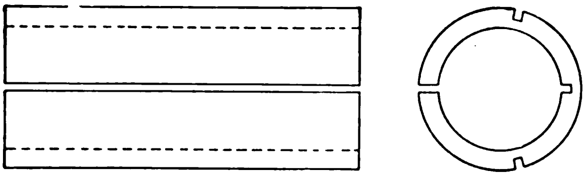


Fig. 64.

If a sleeve is required for a special sized hole, and is to be used but a few times, and through a limited range as to size, it may be made of cast iron. A hole is bored in it corresponding in size and taper to its mandrel; the hole should be made to allow the small end of the mandrel to go through and be flush with the end of the sleeve. The sleeve should be forced on the mandrel and turned to size; the outside diameter should fit the hole in the piece to be machined when the sleeve is at the small end.

In order that the sleeve may be expanded it is split as shown in Fig. 64. This should be done in the milling machine, the sleeve being held by the ends in the vise and the cut made with a metal slitting saw. When the sleeves are intended for permanent equipment it is good practice to make them of either machinery steel or tool steel,— if made of the former they may be case hardened, if of the latter they may be hardened and spring tempered. In either case the hole should be .010 inch small, and the outside diameter .020 to .025 inch large, and ground to size after hardening. A method of splitting the sleeve for a more uniform expansion is shown in Fig. 65; small sizes have four cuts for adjustment, while the larger sizes have six or eight.

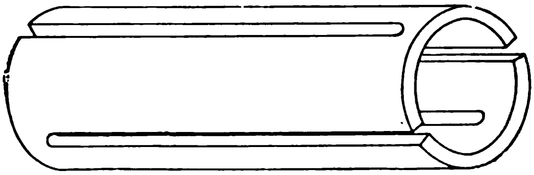


Fig. 65.

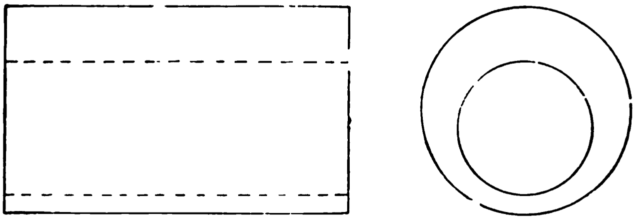


Fig. 66.

On account of the peculiar construction of the sleeve shown in Fig. 65 it must be held while grinding the hole, so that it will not spring. To do this the sleeve may be placed in a hole in a collar and held by several drops of solder so placed as to hold it rigidly in position. In order that the solder may stick, the outside of the sleeve must be brightened. When soldered securely the collar may be placed in the chuck on the grinding machine and the hole ground to the desired size, after which it may be heated to melt the solder, and the sleeve removed from the collar. It can then be placed on the mandrel and the outside diameter ground to the proper size.

Eccentric Arbors. Arbors are made eccentric in order that the outside of a piece of work may be made eccentric to the hole running through it, as shown in Fig. 66.

When making an eccentric arbor the general directions given for making mandrels may be followed, except that the centers should be quite small. The mandrel should be placed in a V block or in a pair of centers, and by means of a surface gauge, the needle of which has been set at the exact height of the center, a line may be drawn, as shown in Fig. 67, across each end of the mandrel. The mandrel may now be turned so that the line will be vertical; the point of the surface gauge may be raised to give the required amount of eccentricity, and a line, as shown in Fig. 68, scribed on each end. The ends should be prick punched where the lines intersect, and drilled and countersunk at this point.

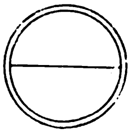


Fig. 67.

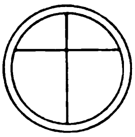


Fig. 68.

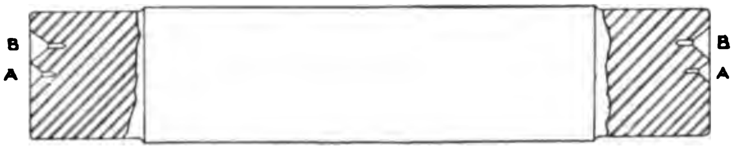


Fig. 69.

After hardening, both pairs of centers should be lapped to shape. The centers marked A A (Fig. 69) must be used when grinding the mandrel to size or in turning work which is to be concentric with the hole, while the centers B B are used when turning the eccentric parts. This method of laying off and drilling the eccentric center may not give the necessary accuracy; in such case a jig must be used in drilling the center holes. A suitable jig is shown in Fig. 70. The ends of the arbor must be turned to fit the hole A, Fig. 70, in the jig, which is a collar having a straight hole through it. A piece of steel, which is a forcing fit in this hole, has a hole the size of the centering drill laid off with the proper amount of eccentricity. This piece of steel is forced to the center of the collar, as shown at B. A straight line should be drawn across the collar and down the beveled edges, as shown at C. A line should now be scribed the entire length of the mandrel, which should be set to match the line on the jig, which may be secured in its proper position by means of the set screws.

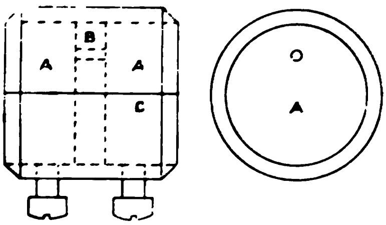


Fig. 70.

For machining a cylindrical piece having a hole through it to receive an arbor, and the faces of the piece not parallel, as shown in Fig. 71, it is well to use a mandrel having two sets of centers, as shown in Fig. 72, one of which, A A, are the regular centers, while the eccentric centers, B B, should be equidistant from the regular centers, but on opposite sides.

Milling Machine Arbors. Arbors for milling machines should be made from steel strong enough to resist (without twisting or springing) the strain caused by tightening the nut. When a limited number of arbors is made, tool steel is generally used: but for many milling machines, necessitating a great many arbors, a lower priced steel having the necessary stiffness is selected.

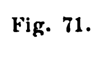


Fig. 71.

After centering and squaring the ends, a chip is turned the entire length of the piece, to remove all the outer surface. The ends D and C, Fig. 73, are next turned to size, and the tenon milled to the desired dimensions; when milling for the tenon, the arbor should be held between centers, and the cutting done with an end mill of the form shown in Fig. 74; the circumference of the cutter, leaving the proper shape at end of tenon. The centers should be hardened, and the temper drawn to a straw color. If the projection on the end of the arbor at C, Fig. 73, is to be run in a socket in the tail block of a milling machine, it must be hardened the entire length, in which case the thread for the nut should be cut before hardening the end. If a lathe having a taper attachment is used, there is no particular method of procedure other than that the arbor should be roughed nearly to size before either the taper or straight end is finished. It will save time, however, if the straight end A, Fig. 73, is roughed first, then the taper B roughed and finished, after which the shoulder E and the straight part A may be turned to size and finished. If the projection C is to run in a socket, it should be turned .010 or .015 inch above finish size, and ground to the proper dimensions.

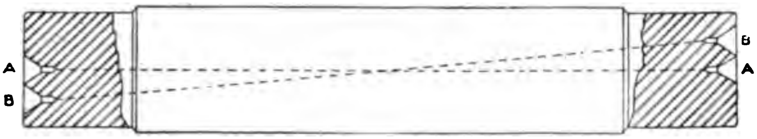


Fig. 72.

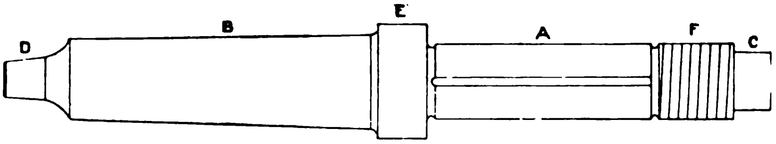


Fig. 73.

If it is necessary to use a lathe having no taper attachment, the necessary taper must be obtained by setting over the tail block. In this case it is better to turn and fit the taper first. If the taper were turned to finish size after finishing the straight part, the centers would become changed to a degree that would throw the arbor out of true. These instructions should be followed wherever a straight and taper surface are to be turned on the same piece of work, in a lathe having no other means of turning tapers except by setting over the tail block.

Milling machine arbors should have a spline slot cut the entire length of the part that is to receive the cutters; this can best be done in a shaper. Before putting the arbor in the shaper vise a hole should be drilled close to the shoulder for the tool to run into; the drill used should be about $\frac{1}{32}$ inch larger in diameter than the thickness of the splining tool, and the hole drilled a trifle deeper than the slot to be cut. When the arbor is placed in the vise a piece of sheet brass or copper should be placed between the arbor and the vise jaws to prevent bruising the arbor.

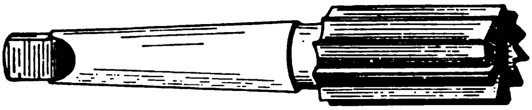


Fig. 74.

Where *extreme* accuracy is required, it is advisable to leave the straight and taper parts a few thousandths of an inch above size and grind to size all over after the spline cut is taken.

The nut is usually made of machinery steel, case hardened. A bar of steel $\frac{1}{16}$ inch larger than finish size of nut is selected, and a piece $\frac{1}{16}$ inch larger than finish length is cut; it is then put in a chuck on the lathe, the hole drilled, and the thread cut; if no tap of the desired size is at hand the thread may be chased. If a tap can be obtained, the thread should be chased nearly to size and finished with the tap; before taking from the chuck the end of nut should be faced and the hole recessed to the depth of the thread for a distance of two threads. After taking from the chuck it should be placed on an arbor having a screw which fits the thread in the nut. The nut should be turned to size and length, and the two opposite sides milled to receive the wrench used in tightening. Fig. 75 gives two views of the nut. It should be made and case hardened before the thread is cut on the arbor, in order that the thread on the arbor may be made to fit the nut. Milling machine arbor nuts should fit the thread on the arbor in such a manner that they may be turned the entire length of the thread without the aid of a wrench, yet not be loose.

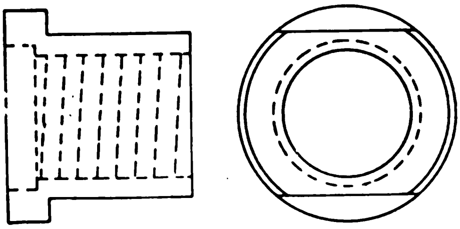


Fig. 75.

TAPS.

When making taps ¼ inch diameter and smaller, the threads are often cut with screw dies, of which there are two styles. The form of screw plate shown in Fig. 76 is termed a *jam die plate.* With this form the die is opened to allow the wire to pass through until it is even with the outside edge of the die, which is now forced into the wire by means of the adjusting screw A; the screw plate is revolved until a thread the desired length is cut. This operation is continued, the die being closed a trifle each time until the desired size is obtained. The method taken of gauging the correct size varies in different shops; if only one is made, the tops of the threads are measured with a micrometer caliper; but for many taps of the same size, such as for sewing machines, guns and bicycles, a sizing die is used to give the threads an exact size. The threads are cut to within a few thousandths of an inch with the die plate, and finished with the sizing die. One form of sizing die is shown in Fig. 77.

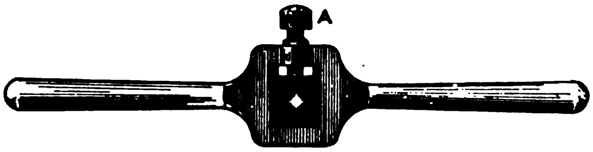


Fig. 76.

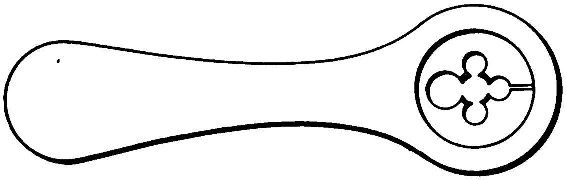


Fig. 77.

Where a great many taps of a size are cut, it is customary to use several dies of different sizes, one of which (the finishing die) is always made adjustable. The roughing dies may be made solid or adjustable, but the finishing must be adjustable for wear, or when it is found desirable to change the size of the taps. These dies are sometimes held in separate holders of the form shown in

Fig. 77, but a very convenient form of holder is shown in Fig. 78. If all the dies are in one holder they do not become scattered around the shop. When making many taps at a time, the work can be done better and cheaper if the wire is held in a chuck in a lathe. The die plate should be placed against a drill pad held in the tail spindle of the lathe, in order to insure starting the threads true. The largest die should of course be run on first, the second largest next and so on to the finish die.

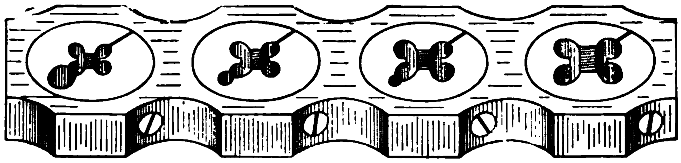


Fig. 78.

For taps up to and including $\frac{1}{4}$ inch diameter, it is customary to use drill rod. The taps should be chamferred for a distance of three or four threads, as shown at A, Fig. 79, in order that the point may enter the drilled hole.

Taps for general use around the shop are often made in sets of three; the first tap to enter the hole is called the taper tap, because of the long chamferring or taper. The second is known as the plug tap; this tap has the first two or three end threads chamferred, and is used when the screw is to go nearly to the bottom of the tapped hole. The bottoming tap is used when the thread is to go to the bottom of the hole being tapped; the end of this tap is not chamferred. See Fig. 80.

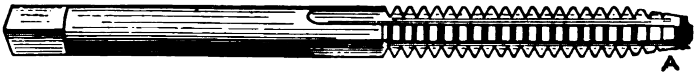


Fig. 79.

Taps larger than $\frac{1}{4}$ inch are made from tool steel. Taps $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter should be made of stock at least $\frac{1}{16}$ inch large; it should be centered quite accurately with a small drill, because a large center hole weakens the tap and increases the liability of its cracking when hardened. After taking a chip sufficiently deep to remove all the outer coating, it should be "box annealed" if possible.

HAND TAPS.

Hand taps are intended for tapping holes by hand and are usually made in sets of three, as previously explained. After annealing, the shank should be turned to size and the square end milled for a wrench. The body should now be turned to size, and the thread cut. Before turning any of the parts to size or starting to cut the thread, be sure that the centers of the lathe are in good condition; the live center should run true, the dead center should fit the center gauge, and be in good shape.

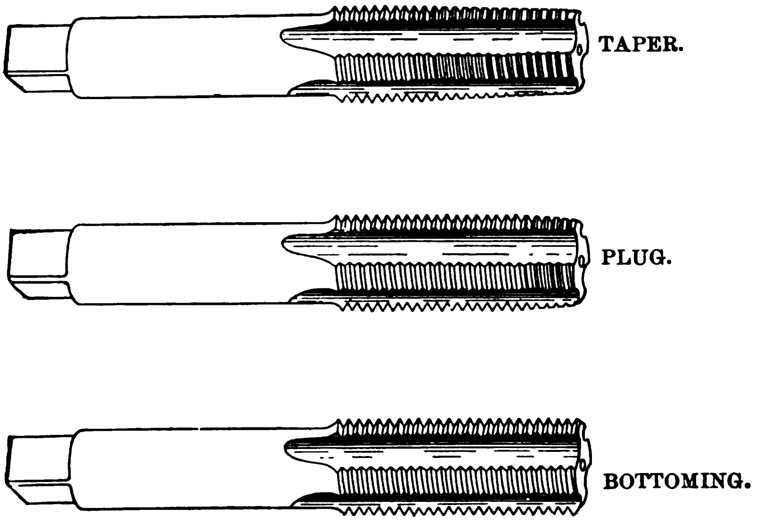


Fig. 80.

It is advisable to cut the tap slightly tapering, the thread being from .0005 to .001 inch smaller at the end toward the shank. This prevents the tap binding when slightly worn, yet it is not tapering enough to affect the accuracy of the thread. The thread tool should be an exact fit to the gauge, and placed in the tool post so that the top of the shank stands about level. The top of blade shown at A, Fig. 81, should be ground parallel with the top of the shank; the cutting point should be set at the exact height of the point of the head center. Many tool makers consider it advisable to rough the thread nearly to size with a single point tool, finishing it with a chaser which may be held in the same holder. A chaser blade is shown in Fig. 82. After the thread is cut to size and the end chamferred, the tap is ready to be grooved in the milling machine. The tap is held between centers and the grooves cut with a cutter especially adapted to the size and style of tap. While the grooves should be cut with a milling machine cutter, it is possible to cut them in a planer or shaper, using a tool of the proper shape. Great care must be used not to stretch the tap by heavy chips, or by using a dull tool.

The grooves cut in taps are ordinarily termed flutes. When making taps for the market it is usual to cut four flutes in all taps up to and including 2½ inches diameter. But when taps are made in the shop where they are to be used, the number and shape of the grooves depend on the nature of the intended work. A tap that is to run through the work without any backing out, can have a different shaped flute from one that is to tap a deep hole in a piece of steel, where it is necessary to reverse the motion of the tap every two or three revolutions to break the chip, and also to allow the lubricant to reach the cutting lips.

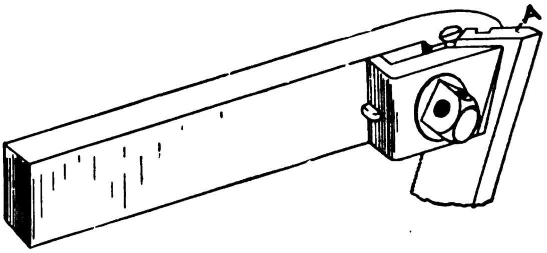
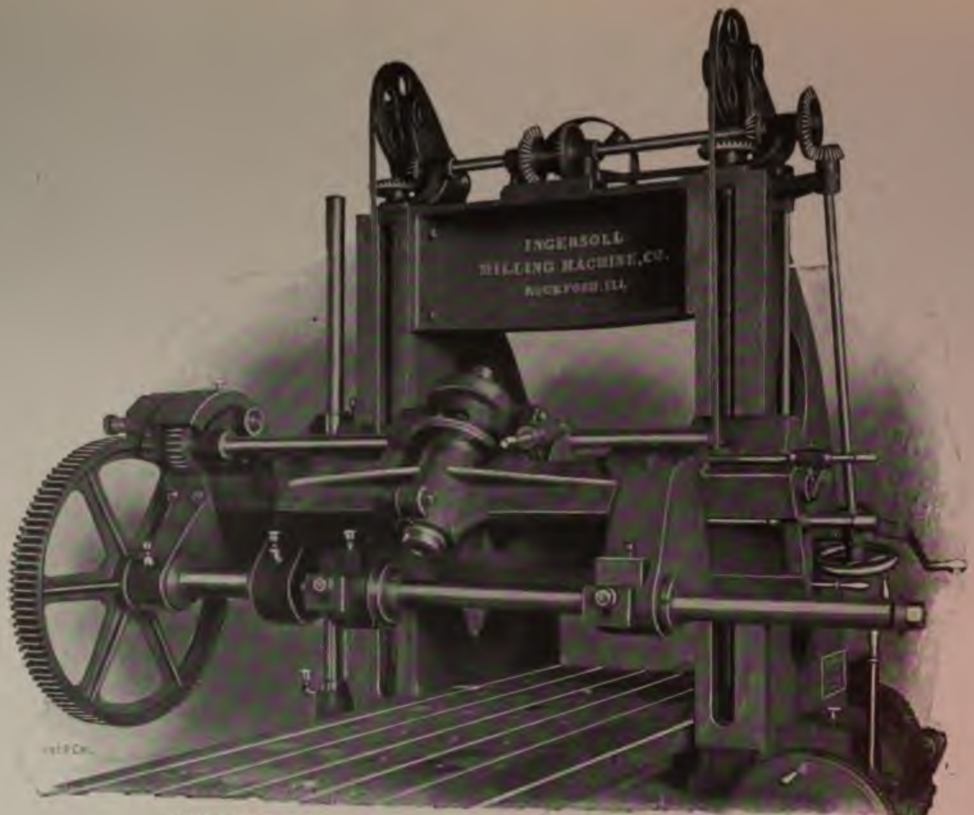


Fig. 81.

While all taps up to and 2½ inches diameter are usually given four straight flutes, spiral flutes are sometimes desirable, especially with small taps for some classes of work. With spiral flutes, it is generally necessary to cut a less number, and as taps are not ground after hardening, there is no objection to giving an odd number of teeth, as in case of a reamer. Three spiral flutes are often cut.

If a tap 1 inch in diameter, having four flutes of the regulation width, were used to tap tubing having thin walls, the tubing



SWINGING VERTICAL ATTACHMENT FOR MILLING MACHINE.

between the lands would have a tendency to close into the flutes of the tap, which might break the tubing. In such a case there should be double the number of flutes, in order to provide enough lands to hold the tubing in shape. If the hole to be tapped has part of its circumference cut away as shown in Fig. 83, more than four lands are necessary.

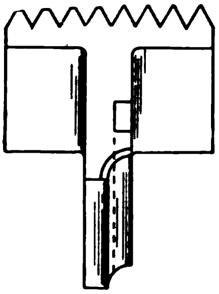


Fig. 82.

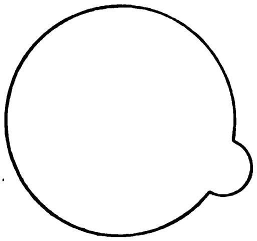


Fig. 83.

However, for general machine shop work four flutes work well in hand taps up to and including 2½ inches diameter. For larger sizes, some tool makers advocate six flutes ; others claim best results from taps having four flutes regardless of size. The class of work and the stock used in the individual shop must determine this.

Forms of Flutes. The most commonly used form of flute is that cut with a convex milling cutter (Fig. 84) for milling half circles. The advantages claimed for this form are: the flutes are of sufficient depth to provide for the chips, and yet leave the lands strong enough ; and the form of the back of the land is such that the chips cannot be wedged between the land and the work when the motion of the tap is reversed. The form of groove made with this cutter is shown in Fig. 85. In order to support the tap when starting to cut, and to prevent cutting the hole large at the outer end, hand taps have their lands left wider (as shown at A, Fig. 85) than is the case with machine taps. If the forms

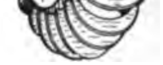


Fig. 84.

If cutters shown in Fig. 85 or Fig. 86 are used, the width of lands as shown at A may be one-fourth the diameter of the tap. A Brown & Sharpe Tap and Reamer Cutter is shown in Fig. 86. Fig. 87 shows a special form of cutter made by Brown and Sharpe. It [illegible] groove (Fig. 88) in proportion to the [illegible] as a Tap and Reamer Cutter.

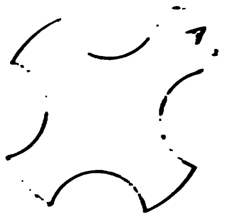


Fig. 85.

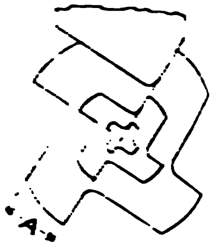


Fig. 86.

After cutting the grooves, the lands should be backed off to give the tap cutting edges; this is usually done with a file. Commence at the heel of the land, A Fig. 89, file the top of the land, and gradually approach the cutting edge, making sure that no stock is removed at that portion; simply bring it to a sharp edge. Enough should be filed off the heel A to make it cut readily, yet not enough to cause it to chatter. The size and number of threads per inch should be stamped on the shank of the tap. If it has a thread differing from that in general use in the shop, that should also be stamped on the shank, as U. S. S., if it is a United States Standard thread.

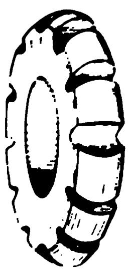


Fig. 87.

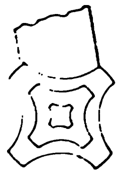


Fig. 88.

The following table gives the number of cutter for different diameters of taps when the form shown in Fig. 87 is used.

No.											
No.	1	Cutter	Cuts	Taps				to	⅛	inch	diameter.
"	2	"	"	"	from	5/32	inches	"	¼	"	"
"	3	"	"	"	"	9/32	"	"	⅜	"	"
"	4	"	"	"	"	7/16	"	"	⅝	"	"
"	5	"	"	"	"	11/16	"	"	⅞	"	"
"	6	"	"	"	"	15/16	"	"	1¼	"	"
"	7	"	"	"	"	1 5/16	"	"	1⅝	"	"
"	8	"	"	"	"	1 11/16	"	"	2	"	"

Hardening. If but a few taps are to be hardened at a time, it is customary to heat them in a gas jet or an open fire of charcoal or hard coal. It is advisable, however, to heat the taps gradually in a tube. They may be plunged one at a time into the bath a little above the threads. The tap should be worked up and down and around in the bath to prevent soft spots. Taps 1 inch diameter and smaller should be left in the bath until cold; if larger they may be removed from the bath as soon as the singing noise ceases, and immediately plunged in oil and left until cold. For taps less than ¼ inch diameter, the citric acid bath will be found satisfactory; for larger taps use strong brine.

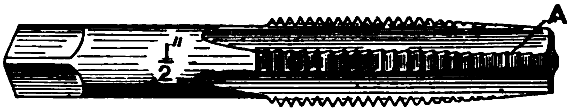


Fig. 89.

To have the tap retain as nearly as possible its size and correctness of pitch, use the "pack hardening" process. Run taps ⅛ inch diameter and smaller, ½ hour after they are red hot; taps ⅛ to ¼ inch diameter, 1 hour; taps ¼ to ½ inch diameter, 1¼ hours; taps larger than one inch diameter, 2 hours. Harden in a bath of raw linseed oil.

Fig. 90.

It is advisable to grind the flutes of the taps with an emery wheel of the proper shape in order to brighten the surface, so that the color may be readily seen when drawing the temper. It also sharpens the cutting edges and breaks the burrs that have been thrown between the teeth when cutting the flutes. The temper should be drawn to a full straw color. Much more satisfactory results may be obtained by heating the taps in a kettle of oil, drawing the temper to a point from 460° to 500°, according to the size of the tap and the nature of the stock to be cut.

MACHINE TAPS.

As the name implies, machine taps are intended for screw machines, tapping machines, and lathes. They are held in chucks or collets by their shanks, and are supported firmly. Consequently the lands may be made narrower than those of hand taps to make them offer less surface to the work, thereby reducing the amount of frictional resistance. Also, they may be relieved between the teeth, by filing with a sharp cornered three square file, commencing at the heel of the tooth and filing nearly to the cutting edge.

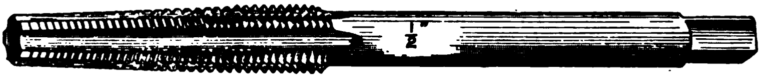


Fig. 91.

It is not good practice to relieve the teeth very much because chips may be drawn between the work and the lands when backing out of the work. When taps are to be used in an automatic tapping machine without reverse motion the shanks are left long as shown in Fig. 90 in order that the nuts may pass over the thread and on to the shank. When this is full the tap is taken from the machine and the nuts removed; this can be readily done as they will pass over the end of the shank.

If a tap is to be used on nuts whose holes are punched to size, much better results are obtained by using a tap having five flutes, as shown in Fig. 91, instead of four. The uneven number of cutting edges reduce the liability of an imperfectly tapped hole, while the extra land furnishes additional support.

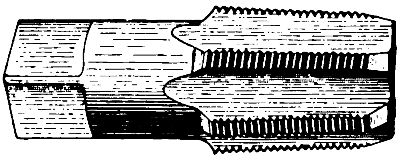


Fig. 92.

Taper Taps. When cutting the threads of a taper tap, Fig. 92, it is necessary to use a lathe having a taper attachment, as the pitch of the threads is not correct if the taper is obtained by setting over the tail stock. Like machine taps, the teeth of a taper must be relieved back of the cutting edge.

In setting the threading tool for cutting taper taps, care should be taken that it is square with the axis of the tap, rather than square with the taper sides.

Screw Die Hobs. Die hobs are finish taps for sizing the thread in screw cutting dies. The several flutes are narrower than those of an ordinary tap and the lands are correspondingly wider. The tap shown in Fig. 93 has eight flutes. The increased number and broader lands support the tap while running through dies whose clearance holes are drilled, in order to remove burrs thrown in the threads when drilling. It is customary to give screw die hobs six to ten flutes.

When hobs are used for solid dies they must be of exact size. When intended for tapping adjustable dies, such as are ordinarily used for cutting threads in screw machine work, the hobs are made from .003 to .005 inch above the size of the screw to be cut. The extra size gives relief to the threads of the die.

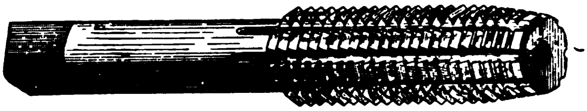


Fig. 93.

While it is generally considered advisable to run one or more taps through a die before the hob, some tool makers consider it better to make a hob that will do all the cutting, claiming that no two taps can be made and hardened so that the pitch will be exactly the same. In such cases a hob (Fig. 94) is made that will cut a full thread by passing through the die.

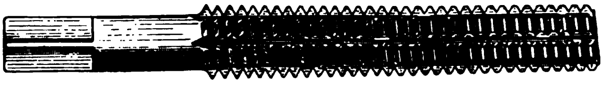


Fig. 94.

Some manufacturers cut the thread tapering for about three-quarters of the entire length of the thread, leaving the balance straight for use in sizing the die. Others cut the thread straight and taper the outside of the thread for three-quarters its entire length. If the threads are cut tapering, they must be relieved back of the cutting edges, as already described.

ADJUSTABLE TAPS.

A solid tap made to cut to exact size, having no leeway for wear, soon becomes too small. This is overcome by making a tap that may be adjusted from time to time. Another reason for making taps adjustable is that the holes may be tapped to fit hardened screws which vary in size on account of having been hardened.

Probably the most common form of adjustable tap is the one shown in Fig. 95. This tap is made in one piece, and then split. It has some means of adjustment whereby the tap may be expanded or contracted through a limited range. This may be accomplished by using a taper bodied screw. The hole to receive the screw should be drilled, tapped and taper reamed, before the tap is turned to size. The thread should then be cut and the taper thread cut on the end at A. There is less tendency to spring when the tap is hardened if the projection shown in Fig. 96 is provided; this may be ground off after the tap is hardened and tempered. After cutting the flutes, the tap may be split in the milling machine using a metal slitting saw; the tap should be held between centers. It is split on two opposite sides, as shown at B, Fig. 95. The splitting should not go to the end of the projection.

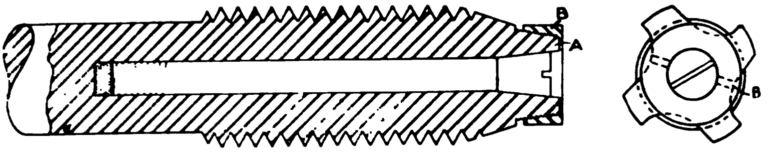


Fig. 95.

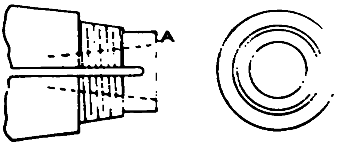


Fig. 96.

For hardening taps "Pack Hardening" is the best method. But, if it is impossible to use this method, heat the tap very carefully in a muffler furnace, or in a tube, having previously plugged the hole for the adjusting screw with fire-clay mixed with water to the consistency of dough. When the tap is heated to the proper degree it should be dipped in a bath of luke-warm brine, and worked up and down rapidly. After hardening, it should be ground in the flutes, and the temper drawn to a full straw color. The projection on the end may be ground off, the taper screw inserted, and the locking nut B, Fig. 95, screwed to place. This nut has a taper thread cut inside to correspond with the thread on the tap at A, Fig. 95. It will be found necessary to cut the taper thread on the tap and in the nut by means of the taper attachment.

Inserted Blade Taps. The first cost of an inserted blade tap may not be much less than that of a solid tap of the same size, yet on account of the comparatively small cost of new blades which can be inserted in the same body, or holder, when the first set becomes worn, this form is very valuable for taps larger than $1\frac{1}{2}$ inches diameter. The tap shown in Fig. 97 may also be used as an adjustable tap. The shank or holder A is made of machinery steel, and the adjusting collars C C are beveled on the inside at one end at an angle corresponding to the angle on the ends of the blades. An angle of 45° will be found satisfactory.

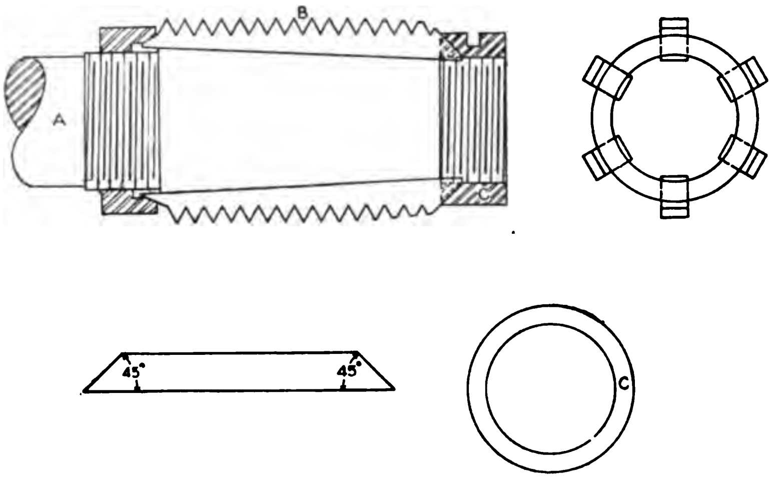


Fig. 97.

After turning the body, or holder to size, and cutting the threads to receive the nuts, the slots for the blades may be milled;

[illegible] should be [illegible] taper in the milling and in order that any change in the [illegible] of the blades may alter the size of the tap. A taper of [illegible] in three inches is ample. If the slots are milled in the universal milling machine, and the tap held in the universal centers the spiral head may be depressed sufficiently to give the desired angle. If a pair of centers of the form shown in Fig. [illegible] are used they may be held in the milling machine vise at

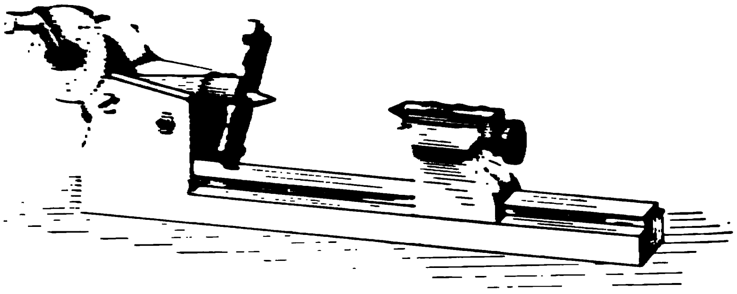


Fig. 95.

the desired angle. The milling cutter should be set about $\frac{1}{32}$ inch ahead of the center in order that the face of the blade may be milled enough to make any inequality in the teeth at the cutting face of the blade [illegible] thread tool striking the face

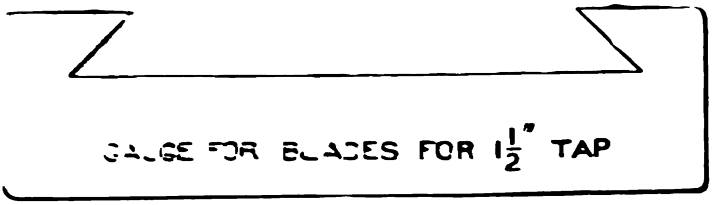


Fig. 96.

when it starts to cut. The amount milled from the face should be just enough to leave the cutting face radial. The blades should be of an exact length and should fit accurately in the slots. A gauge of the form shown in Fig. 96 will insure uniform length. After the blades have been carefully fitted to the slots and to the gauge, they may be inserted in the holder and secured by the nuts as shown in Fig. 97. The outside diameter is then turned about

.005 inch smaller than the size the tap is to cut and the threads very carefully cut; after which the face of the blades may be milled as explained, the cutting end chamferred, and the necessary amount of clearance given the cutting edges by filing. The blades are now ready for hardening.

When hardening, the blades should be subjected to a slow heat in a muffler furnace, or a tube. When a blade reaches a low uniform red heat, it should be immersed in a bath of luke-warm water or brine, and worked up and down to insure uniform results. After hardening it may be brightened and drawn to a deep straw color. It is well to place all the blades in a pan having a long handle, as shown in Fig. 100. Coarse sand to a depth of about $1\frac{1}{2}$ inches may be placed in the bottom of the pan with the blades. The pan should be placed over a bright fire and shaken carefully so that the teeth will not be dulled by striking the other hardened blades, while the sand and the blades are heating. The motion causes it to heat uniformly and the sand keeps the surface of the work bright so that the temper colors may be readily seen. This method of drawing temper will be found very satisfactory on many classes of work. It is also used extensively when coloring pieces by heat where a great many pieces are to be colored uniformly.

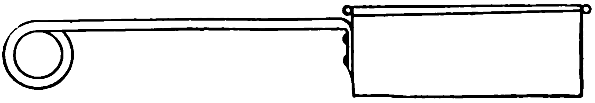


Fig. 100.

Square Thread Taps. Although the square thread is not as extensively used as formerly, having given place in many shops to the "Acme Standard," yet it is sometimes necessary to make taps for this form.

Steel should be selected sufficiently large and the decarbonized portion removed; the shank should be turned to size. The square should be milled for a wrench and the size and number of threads per inch stamped on the shank. The cutting end of the tap should be turned to size, the necessary amount of taper given the tap and then the threads cut

The tool used for cutting square threads is similar in form to a cutting-off (parting) tool except for its angle of side rake; it should be made of the proper thickness at the point but should be somewhat narrower back of the cutting end, as shown in Fig. 101, in order that it may clear when cutting.

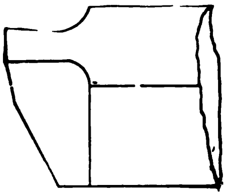


Fig. 101.

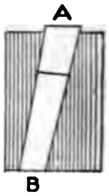


Fig. 102.

The thickness of the cutting end should be one half the distance from the edge of one thread to the corresponding edge of the next thread. For a square thread of 2 pitch, the land and space together would be ½ inch, while the land and space would each be ¼ inch wide. The point of the tool would be ¼ inch thick.

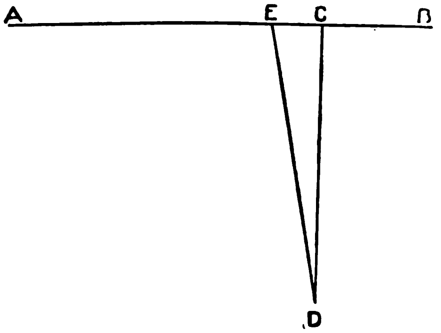


Fig. 103.

The sides of the tools from A to B, Fig. 102, must be inclined to the body as shown, the amount of the inclination depending upon the pitch of the thread and diameter of the tap to be cut. It may be determined, however, by the method shown in Fig. 103. Draw the line A B, and at right angles to it draw C D, whose length must be equal to the circumference of the thread to be cut, measured at the bottom or root of the thread. On A B lay off from the point C a distance E C equal to the pitch of the thread to be cut. Then draw the line D E, which will represent the angle of the side of the thread; the angle of the side of the cutting tool must be sufficiently greater to give the necessary clearance. It is advisable to cut the thread with a tool somewhat narrower than the required width at first, and finish with a tool of the proper thickness.

Square thread taps may be fluted according to directions given for V thread taps. If a tap is intended to cut a full thread, it must be well backed off, in order to avoid the necessity of using so much force that the tap would be broken. When a tap is to be used to size a hole whose thread has been cut by a smaller tap, very little clearance is necessary.

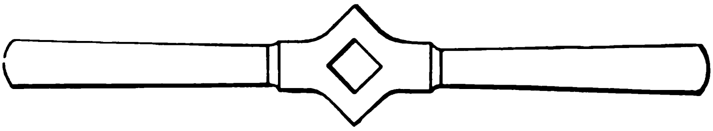


Fig. 104.

Tap Wrenches. When taps are used whose squares are all of a size, a solid tap wrench may be made, as shown in Fig. 104. This wrench is forged nearly to shape, the handles turned to size in the lathe, and the square hole in the center drilled and filed.

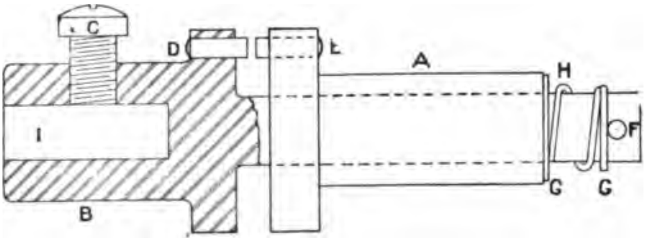
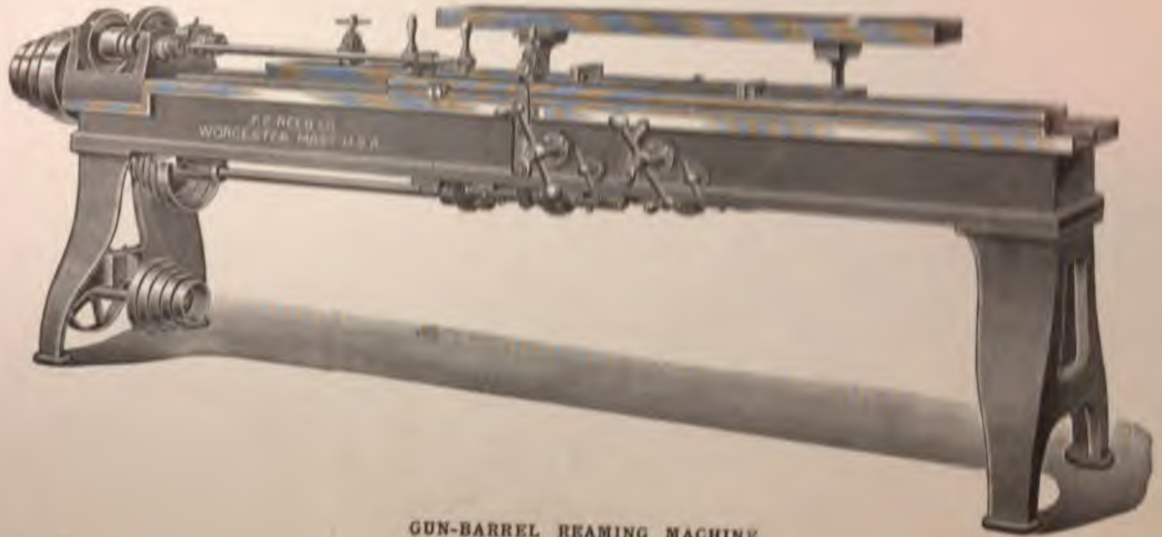


Fig. 105.

Releasing Tap Holders. When holes are to be tapped to a uniform depth in a screw machine or turret lathe, a tap holder is used which automatically releases the tap when it reaches the required depth. A very common form which gives excellent results when properly made and adjusted is shown in Fig. 105. It consists essentially of a sleeve A, which fits the tool holes in the turret of the screw machine, and the tap holder B, which fits the hole in the sleeve in such a manner as to slide longitudinally. The sleeve A should be made of tool steel if of a diameter that makes the wall around the hole thin; the hole should be drilled and reamed to size, and the outside turned to size. The portion of the sleeve which enters the hole in the turret should be a snug fit. The tap holder B should be made of tool steel, or of a grade of machinery steel possessing great stiffness and good wearing qualities. After roughing out to sizes somewhat larger than finish, the end which is to hold the tap may be turned to size and the (stem) end which is to run in the sleeve may be fitted, after which the hole I, to receive the tap may be made of a convenient size. In order that the hole may be perfectly concentric with the holder it will be necessary to run the large end of the holder in the steady rest of the lathe; the opposite end should be fastened against the head center of the lathe in such a manner that the stem runs perfectly true. With work of this nature, the head center of the lathe must be in good condition and run true.

After the hole has been drilled somewhat smaller than finish size, it is necessary to true the hole with a boring tool; the hole should be bored to within .010 inch of finish size, after which it may be reamed with a rose reamer. Before reaming, however, the outside edge of the hole should be chamferred to the shape of the point or cutting end of reamer, to avoid any possibility of the reamer running. Some tool makers never ream a hole of this nature if it can be avoided, always boring to size with a tool that makes a smooth cut; but if extreme care is used, results good enough for a tool of this character may be obtained if the holes are finished to size with a reamer.



GUN-BARREL REAMING MACHINE.
F. E. Reed Company.

TOOL MAKING.

PART II.

THREAD CUTTING DIES.

The size of a die is always denoted by the diameter of screw it will cut; a die that will cut a $\frac{1}{2}$ inch screw is called a $\frac{1}{2}$ inch die, irrespective of the outside diameter of the die itself.

Thread cutting dies are made solid or adjustable. Solid dies are used when extreme accuracy is not required. They are comparatively inexpensive, and may be used to advantage as a roughing die when an adjustable die is used for finishing. Owing to the tendency of dies to change their sizes when hardened, and to the fact that there is no provision for wear, they cannot be used where work must be made to gauge. They are extensively used in cutting threads on bolts, and for this class of work are made square, as shown in Fig. 106.

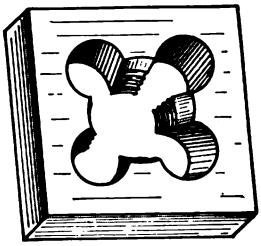


Fig. 106.

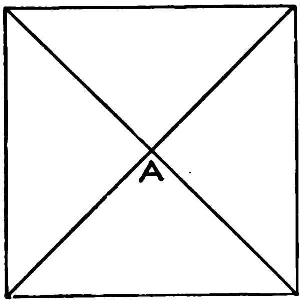


Fig. 107.

In making a square die the blank may be machined to thickness and to size on the square edges. One of the flat surfaces should be coated with blue vitriol, or the blank may be heated until it shows a distinct brown or blue color. The center may be found by scribing lines across corners, as shown in Fig. 107. It should be prick punched at A where the lines intersect. The die blank may be clamped to the face plate of a lathe and made to run true by means of the center indicator. If there is no tap of the proper size, and only one die is to be made, the thread may be cut with an inside threading tool, provided the hole is of sufficient size; if not, a tap must be made. If the thread is cut with a threading tool, the size must be determined by means of a male gauge, which may be a screw of the proper size. After threading, the hole should be chamferred to a depth of three to four threads, the amount depending on the pitch of the thread; a fine pitch not requiring as many threads chamferred as a coarse pitch. The chamferring should not be much larger on the face of the die than the diameter of the screw to be cut. Figs. 108 and 109 show two views of a die chamferred and relieved on the cutting edges. The chamferring may be done with a countersink or taper reamer of the proper angle. In the absence of such a cutter, a tool held in the tool post of the lathe may be used.

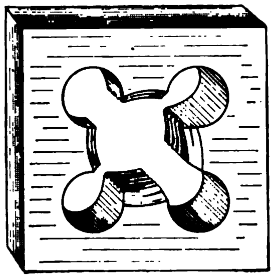


Fig. 108.

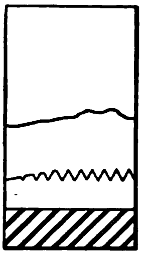


Fig. 109.

Most manufacturers making dies for the market give four cutting edges to all sizes up to and including four inches. When dies are made in the shop where they are to be used, custom varies. Some tool makers advocate three cutting edges for all dies smaller than ¼ inch, and five or more cutting edges for dies above two inches. The objection to more cutting edges than are absolutely needed on large dies is the increase in the cost of making.

When making dies for threading tubing, or for work where part of the circumference is cut away, it is better to give them a greater number of cutting edges than would otherwise be the case.

Rake of Cutting Edges. For general shop work, where the dies are to be used for all kinds of stock, it is advisable to make the cutting edges radial as shown in Fig. 110, the cutting edges

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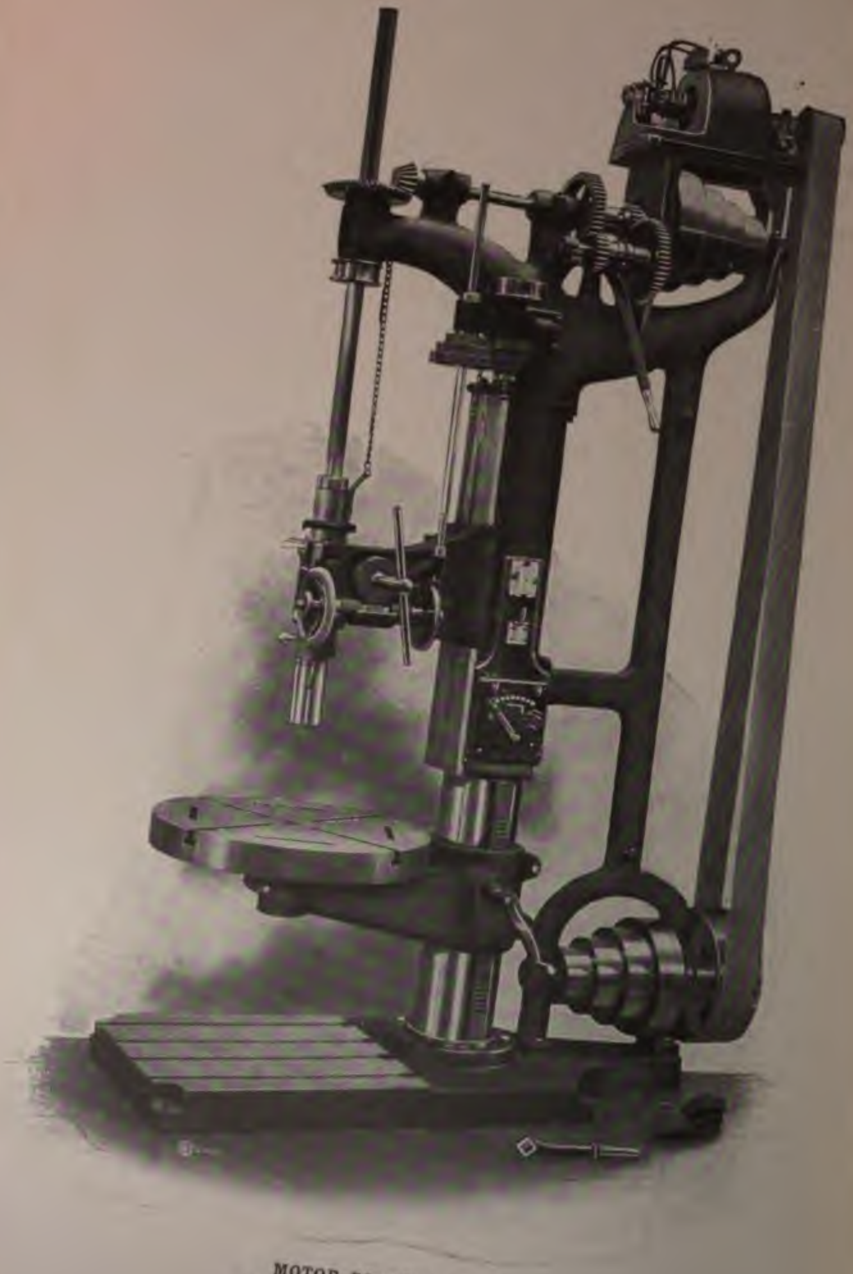


MOTOR-DRIVEN DRILL.
The Hamilton Machine Tool Co.

A A A A all pointing to the center. For cutting brass castings, the cutting edges should have a slight negative rake as shown in Fig. 111, the cutting edges A A A A all pointing back of the center.

Clearance Holes. After threading and countersinking (chamferring), screw in a piece of steel threaded to fit the die, and face it off flush. Lay out the centers of the clearance holes on the back of the die, and drill with a small drill the size of the pilot of a counterbore whose body will cut the right size for the clearance hole. The centers of these holes for dies having four cutting edges, and from ⅜ to ¾ inch may be the intersections of a circle having a diameter equal to the diameter of the screw to be cut, and lines drawn across the corners as shown in Fig. 112. Prick punch these points. For a die having four clearance holes whose centers are laid out as shown in Fig. 112, it is customary to make the clearance holes one half the size of the die; that is the size of clearance holes in a ½ inch die would be ¼ inch. The width A, Fig. 113, of the top of the lands should be about $\frac{1}{16}$ of the circumference of the screw to be cut. The diameter of clearance holes given does not apply to dies smaller or larger than sizes given (⅜ to ¾ inch), especially if the dies are to be used in the screw machine, as the clearance hole not only

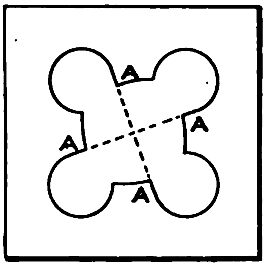


Fig. 110.

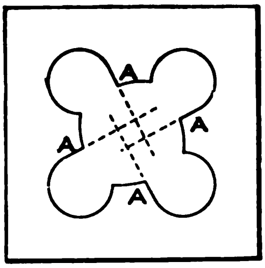


Fig. 111.

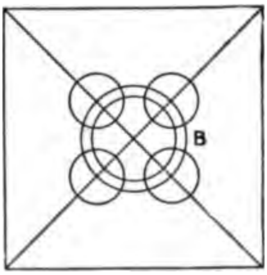


Fig. 112.

provides a cutting edge, but also makes a convenient place for the chips: if these are so small that the oil cannot wash the chips out, the chips clog the holes and tear the thread.

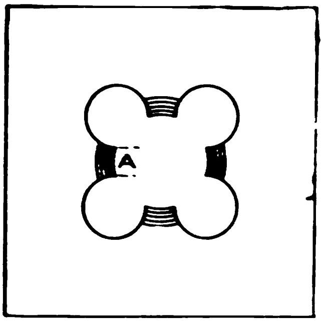


Fig. 113.

For small dies the clearance holes are of a size that allows the chips to collect in the holes without tearing the threads, and are located a greater distance from the center of the die, in order to give sufficient strength to the lands. The desired shape and thickness may be given the sides of the lands by filing. When it is considered advisable to give screw dies above ¾ inch larger clearance holes than the size mentioned, they may be located at a distance from the center of the die that will give the desired thickness to the land.

For screw machine and turret lathe work, dies are generally made circular, and as holders for dies are part of the equipment of every shop having screw machines, the dies should be made to fit these holders: but it is not considered good practice to make the diameter of dies less than 2½ times the diameter of the screw to be cut, and the thickness of the die may be 1¼ times the diameter of the screw.

ADJUSTABLE DIES.

While round dies for screw machine work may be made solid for roughing out a thread that is to be finished by another die, the finish die should be made adjustable in order that the desired size may be obtained. When making adjustable dies the same general instructions may be followed that are given for making solid dies, except that some provision must be made for adjustment. This is done by splitting the dies at one side as shown at A in Fig. 114. In order that the die may not spring out of shape in hardening, it is advisable to cut the slot from the center of the die, leaving a thin margin as shown at A, Fig. 115; after the die is hardened this may be cut away with a beveled emery wheel. If the thickness at B is too great to allow the die to close readily when adjusted to size, the hole shown may be drilled and connected with the clearance hole by means of a saw cut.

If many round dies of the same diameter are to be made it is economical to have a holder with a shank which fits the hole in the spindle of the lathe; the opposite end should be made to receive the die blanks which should be turned to fit the die holder in the screw machine. Fig. 116 shows the holder to be used in the lathe. A represents a die blank in the holder; B is the shank which fits in the spindle of the lathe; C is a recess in the holder to provide for the projection left on the blank when it is cut from the bar and also provide an opening to receive the drill and tap after they run through the die. After the blank is placed in the holder and secured in position by the screw D, the outer surface may be faced smooth and true with the circumference, after which it may be reversed and the opposite side finished to the proper thickness. The die may now be drilled and tapped. Be-

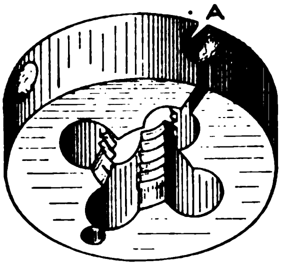


Fig. 114.

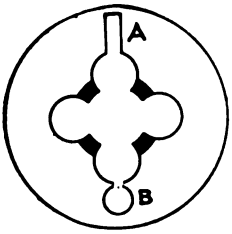


Fig. 115.

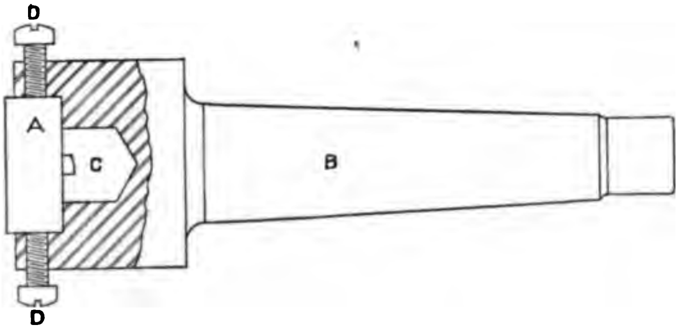


Fig. 116.

fore drilling, the die should be carefully centered in the lathe; to insure a full thread in the die, a drill a few thousandths of an inch smaller than tap size should be used in drilling, after which a reamer of the proper size may be run through. When tapping the thread, it is advisable to use two or three taps of different sizes; the finish tap should be the size of the desired hole in the die, and should be of the form known as screw die hob. Where several taps are used in tapping a die, there should be some difference in the diameter so that any inequality in the shape or pitch of the thread may be removed by the larger tap, otherwise imperfect threads will result. For instance if three taps are to be used for a ¼ inch die, the first tap may be .230 inch diameter; the second .240 inch diameter, and the finish tap .250 inch diameter if the die is to be solid. If it is to be an adjustable die, the finish tap should be .253 inch diameter in order to furnish clearance to the lands when it is closed to .250 inch.

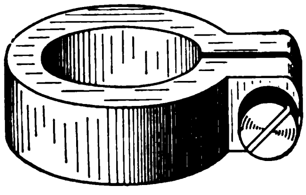


Fig. 117.

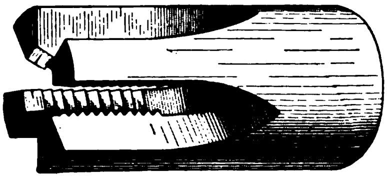


Fig. 118.

Dies should be heated very slowly for hardening, either in a muffler furnace, or in some receptacle to protect it from the action of the fire. When the die is heated to a uniform low red it may be immersed in a bath of lukewarm brine and worked back and forth to insure hardening the threads. The temper should be drawn to a full straw color. If it is an adjustable die the portion marked B, Fig. 115, should be drawn to a blue color in order that it may spring without breaking; this may be done by placing this portion of the die on a red hot iron plate, or the jaws of a heavy pair of tongs may be heated red hot, the die may be grasped in the tongs and held until the desired color appears. Do not allow the blue color to extend to the threads or they will be too soft. When the desired color has been obtained the die may be dropped into oil to prevent drawing the temper more than is desired.

Spring Screw-threading Dies. This form of die is adjusted by means of the clamp collar shown in Fig. 117; the die is shown in Fig. 118. In some shops it is the only form of screw-threading die used for screw machine work. When so used it should be fitted to one of the holders on hand, provided there be one of the proper size.

Average proportions of spring dies are given in the following table; these sizes are used by a manufacturing concern using a great many screw-threading dies of this description. It is not necessary to follow the proportions given, as they are intended only as a guide, and may be changed to suit circumstances. All dimensions are in inches.

SPRING SCREW-THREADING DIES.

Size of Screw.	Outside Diameter.	Length.
$\frac{1}{8}$ to $\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
$\frac{1}{4}$ to $\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$	1	2
$\frac{1}{2}$ to $\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$
$\frac{3}{4}$ to 1	$1\frac{5}{8}$	$2\frac{1}{2}$
1 to $1\frac{1}{4}$	2	3
$1\frac{1}{4}$ to $1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$
$1\frac{1}{2}$ to 2	$3\frac{1}{4}$	4

For uniform and well-finished threads, two dies should be used, one for roughing, and one for finishing.

Where many dies of a size are made it is best to have a holder with a shank fitting the center hole of some lathe. The stock can be machined to size and cut to length. The clearance hole in the back of the die should be first drilled somewhat larger than the diameter of the screw to be cut. For dies up to and including $\frac{1}{8}$ inch the clearance holes should be $\frac{1}{32}$ inch large; for dies $\frac{1}{8}$ to $\frac{1}{4}$ inch it should be $\frac{3}{64}$ inch large; for dies $\frac{1}{2}$ inch and over, it should be from $\frac{1}{16}$ to $\frac{1}{8}$ inch large. After drilling the clearance hole, the die should be reversed in the holder, and drilled and tapped the same as a round die, using a hob to finish the threads to size. For general work, the die should have four cutting edges making the lands about one-sixteenth the circumference of the screw to be cut. Chamfer about three threads. The length of the threaded portion of the die should not exceed one and one-quarter times the diameter of the screw to be cut. To produce the cutting edges, use a 45° double angle milling cutter shown in Fig. 119; this cutter should be of sufficiently large diameter to produce a cut as shown in Fig. 120.

The chamferred edges should be relieved and the cutting edges finished with a fine file. Stamp the size and number of threads on the back end of the die as shown in Fig. 120 and then harden. The die should be heated in a tube and hardened in a jet of water coming up from the bottom of a tank in order that the water may enter the threaded portion. It should be hardened a little farther up than the length of the thread, moving up and down in the bath to prevent a water line; the temper should be drawn to a full straw color.

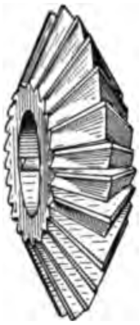


Fig. 119.

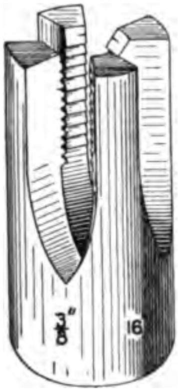


Fig. 120.

Where many clamp collars are used, castings of malleable iron or gun metal may be made from a pattern; the hole should be cored to within $\frac{1}{16}$ inch of finish size. The hole may then be drilled and reamed. When the screw hole has been drilled and tapped and the collar split, it is ready to use. If the surfaces are finished it adds very materially to the cost.

Die Holders. When cutting threads in screw machines and turret lathes, dies are held in die holders which are constructed in two parts as shown in Fig. 121. The shank A fits the hole in the turret, while the die holder B has a stem that fits the hole in the shank. While the die is cutting, the pins D and C are engaged, thus preventing the holder B from turning. When the turret slide of the screw machine has traveled to its limit, the holder is drawn out of the shank until the machine is reversed when the pins engage on their opposite sides. A pin is put through the stem of the holder at E; this strikes the end of shank just at the time the pins D and C become disengaged.

Both shank and body may be made of machinery steel; the shank may be finished to size except the portion marked A, which should be left .010 inch large for grinding. The front end of the hole should be rounded as shown in Fig. 121, to allow the fillet in the shoulder of the stem to enter. This fillet is left for strength. The pin hole should be drilled and reamed. When the holders are to take dies not over $\frac{1}{8}$ inch in size, this pin hole may be $\frac{3}{16}$ inch diameter; from $\frac{1}{8}$ to $\frac{5}{16}$ in size, $\frac{1}{4}$ inch diameter. As the dies

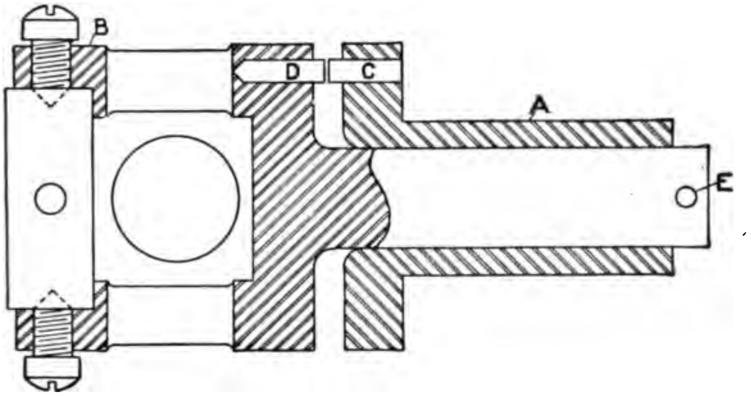


Fig. 121.

increase in size the pin must increase proportionately. The shank may be case-hardened in a mixture of granulated charred leather and charcoal; it should run about two hours and then be dipped in a bath of oil. The hole should be lapped straight and true. The outside ground to fit the hole in the turret. The pin C should be of tool steel hardened and drawn to a blue color, and forced into place.

The holder B may be made from a forging, or turned from a solid piece. After roughing to size somewhat larger than finish, the stem may be turned and fitted to the hole in the shank; it should turn *freely* in the shank. The larger portion (or body) should now be turned to size. This should be run in the steady rest, and the end drilled and bored for the die and for clearance back of the die as shown in Fig. 121. Three or four large holes should be drilled into the clearance hole in order that the chips and oil may find a way of escape, thus preventing injury to the threads of a screw long enough to reach through the die when being threaded.

Screw holes should be drilled and tapped as shown in Fig. 121; the screws are to hold the die in position in the holder and also to adjust to size dies that are split. The stem may be placed in the shank and the pin hole transferred through the pin hole in the shank into the body; this should be done before the pin C is pressed into place. The pin D should be hardened the same as C.

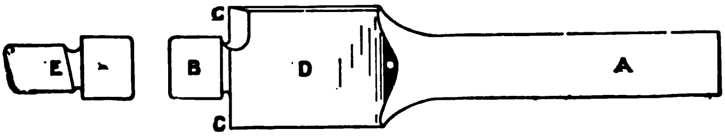


Fig. 122.

The pin hole for the pin E may be drilled in a location that allows C and D to become disengaged and yet have no play between the two

COUNTERBORES.

Counterbores are used for enlarging a hole without changing its relative position. For a *hurry up* job and for a small number of holes, it is advisable to make as cheap a form as is consistent with the work to be done. Probably the cheapest counterbore that will do satisfactory work is the flat form shown in Fig. 122. This can be forged to require but little machine work. After forging, turn to size; finish the shank A and pilot B with a fine file before taking from the lathe. The cutting edges C C should be faced true and smooth. The necking between the pilot and the body should be cut with a tool having the corners slightly rounded to decrease the liability of cracking when the counterbore is hardened. The flat sides D of the body may be finish filed; the edges should be draw-filed, removing more stock on the back than on the cutting edge to prevent binding. File the cutting edges C C for clearance, as shown at E, Fig. 122. The pilot and the body should be hard the entire length or they will wear and rough up and consequently cannot cut a smooth hole; draw the temper to a full straw color. Unless intended for *accurate* work it need not be ground.

For permanent equipment, counterbores are usually made with four cutting edges as shown in Fig. 123 and Fig. 124. Fig. 123 representing a taper shank counterbore for a taper collect, while Fig. 124 has a straight shank to be used in a chuck, or collet having a straight hole the size of the shank.

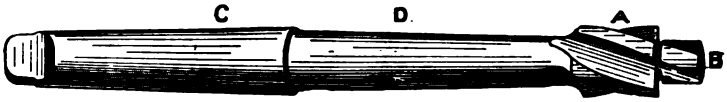


Fig. 123.

Counterbores for screw holes are usually made in sets of three, one for the head of the screw with pilot (or guide) of body size, one for head with pilot of tap drill size, and one to enlarge a tap drill hole to body size. The following instructions apply to counterbores with either straight or taper shanks. Take stock somewhat larger than finish size of counterbore.

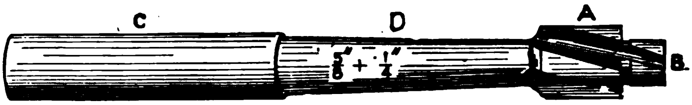


Fig. 124.

Turn a roughing chip all over the piece; turn the necked portion between the shank and body to size and stamp size of counterbore and pilot as shown in Fig. 124; turn shank C, body A, and pilot B .015 to .020 inch above finish sizes, to allow for grinding. In the case of the taper shank counterbore shown in Fig. 123 the tennon should be milled. The counterbore is now ready to have the grooves milled to form the cutting edges. One method is to cut them with a right-hand spiral of from 10° to 15°; the other method is to cut the grooves straight. The former has he effect of running chips back from the cutting edges and works very well on wrought iron and steel, while the latter method is considered more satisfactory for brass and cast iron and also works well on wrought iron and steel. The cutting edges are given clearance by filing, as shown at A in Fig. 125. If the counterbore is to be used for brass it is necessary to give clearance to the lands also as shown at A A A A, Fig. 126.

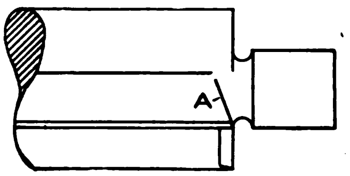


Fig. 125.

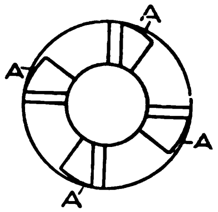


Fig. 126.

When centering counterbores or any tools whose centers are not to be used after the tool is finished, the drill should be small and the countersinking no larger than is necessary for good results in machining. If large centers should, by accident, be put in the ends, the one on the end to be hardened should be filled with fire clay moistened with water to the consistency of dough, or with graphite mixed with oil; this prevents steam forming in the hole and cracking the tool when dipped in the bath. If the piece is to be heated in lead, the filling should be dried thoroughly before immersing in the red-hot lead.

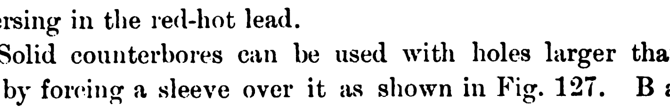


Fig. 127.

Solid counterbores can be used with holes larger than the pilot by forcing a sleeve over it as shown in Fig. 127. B and C are two views of the sleeve which is to be forced on to pilot A. After hardening, the counterbore may be ground to size on the shank, body and pilot; the shank should be ground first as the length is greater, and in the case of a counterbore having a straight shank the grinder may be adjusted to perfect alignment by measurement.

Two lipped counterbores are sharpened by grinding on the flat faces marked D, Fig. 122. Grind a four-lipped counterbore on the flat side of the groove as D in Fig. 127.

Facing Tool with Inserted Cutter. Where a limited number of holes are to be counterbored, the tool shown in Fig. 128 may be made. All that is necessary in making this tool is a piece of stock A, the size of the hole to be counterbored and a piece of drill rod for the cutter B; this may be filed to a cutting edge, hardened and driven in place. If accuracy is essential, a piece of drill rod must be cut off somewhat longer than the diameter of the required hole; it should be driven into the hole in the bar leaving an equal length on each side. It may be turned to the correct diameter and filed to shape. If several cutters are to be used in the same bar, or if the tool is to be used as a facing bar, to square a shoulder inside a piece of work as shown in Fig. 129, the cutter B is removed from the bar and after the bar is in place it is inserted and held by set screw C.

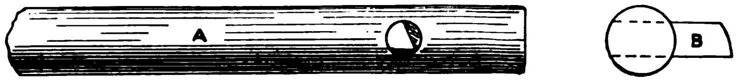


Fig. 128.

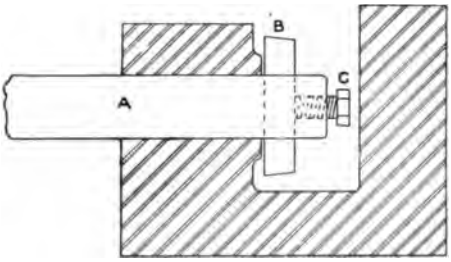


Fig. 129.

For large work, a counterbore may be made as shown in Fig. 130, A being the cutter bar which should be made of tool steel $\frac{1}{16}$ to $\frac{1}{8}$ inch larger than finish size. After taking a roughing chip, leaving it a trifle large, the slot should be made to receive the cutter C. This is done by drilling a series of holes as shown in Fig. 131. After prick punching the bar, it should be clamped to a drill press table, holding the bar in a pair of V blocks. The prick punch marks should be set in a position that will insure the drill holes going through the center of the bar; this can be done as follows: place the square against one side of the bar, measure to the center, then place the square against the opposite side and measure in the same manner. When the distance is the same on each side from the square blade to the centers, the piece is in the proper position for drilling. The drill press table may then be swung around until the prick punch marks are in proper location with the spindle of the press. After drilling, a drift may be driven through to break the walls separating the holes and the slot filed to size. The bar should be placed with one end in the steady rest and the other end strapped to the head center of the lathe. The screw hole in the end is now drilled and tapped into the slot in order that the screw may bind the cutter. The end should be countersunk to provide a center for finish turning. The bar may be turned to size at A and the pilot finished to size. The screw D should have a head $\frac{1}{16}$ inch larger than the part B in order that it may hold the sleeve in place, should it have a tendency to come off when removing the counterbore from the hole. The cutter C should be a close fit in the slot. A headless screw should be made short, so that it will not interfere with the dead center of the lathe when it is screwed to place against the

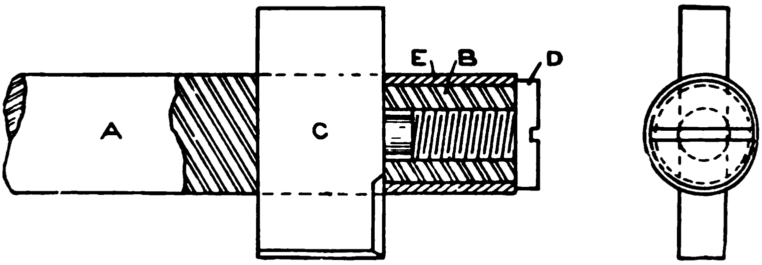


Fig. 130.

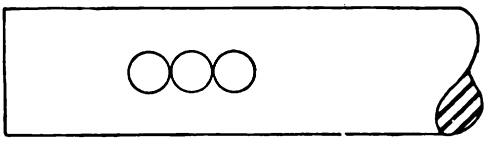
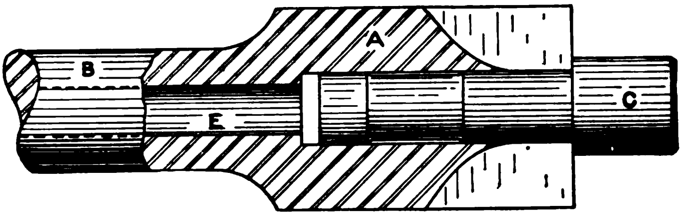


Fig. 131.

cutter blank. It is intended to be used when turning the cutter to the right diameter, and should be kept for that purpose.

Counterbores with Inserted Pilots are useful when the counterbores need frequent sharpening, or when a variety of different sized holes are to be counterbored to the same size. A common form of counterbore having an inserted pilot is shown in Fig. 132.



Fig, 132.

When making this counterbore the stock should have a roughing chip taken off and the hole E drilled part way from the shank end. This drilling may be done in the speed lathe, holding the drill in a chuck in the head spindle ; the center in the opposite end of the piece should be on the dead center of the lathe. If the piece is turned one-half revolution occasionally the drill will cut accurately enough, as perfect alignment is not necessary in this hole, since it is intended only for use when driving out the pilot.

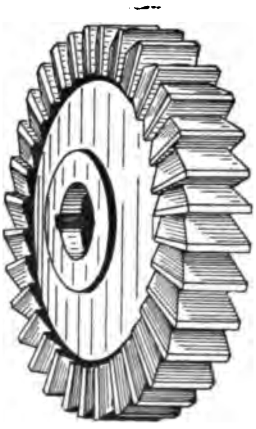


Fig. 133.

After drilling, the shank end should be carefully countersunk. The piece may now be turned to grinding size which should be from .015 to .020 inch all over. After turning the outside, the hole for the pilot may be drilled and bored, running the large end of the counterbore in the steady rest. The counterbore should have four cutting edges for all ordinary work ; these may be cut with a side milling cutter with a face sufficiently wide to cover the width of tooth. The form of cutter is shown in Fig. 133, while an end view of the teeth is shown in Fig. 134. When mil-

[illegible] in the chuck on [illegible] needed than [illegible] may be tipped to [illegible] instead of sink into [illegible] should be removed, the [illegible] hardening it should [illegible] when dipped [illegible] that the teeth may be [illegible] rapidly in the [illegible] It should be allowed [illegible] 1 inch diameter [illegible] from the [illegible] The pilot [illegible] A and BB should be left

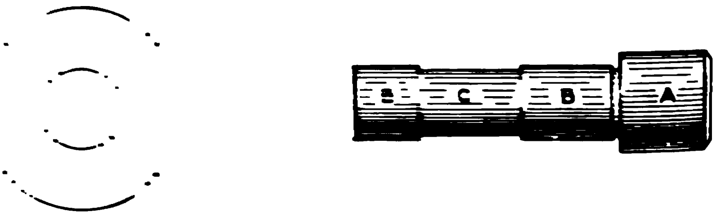


Fig. 155.

[illegible] after hardening: C should be [illegible] this does not [illegible] A slight depression should be [illegible] point B for the emery [illegible] When hardening, A is the [illegible] unless a piece of tube is [illegible] is put in the bath it will [illegible] A the entire length and leave B [illegible] used it is best to harden [illegible] unless there should be a great dif- [illegible] which case a tube, or a piece [illegible] the size of B and having the [illegible] should be slipped over B when [illegible] should be slipped over the stem [illegible] the head to prevent a *water line*:

if this precaution is taken there is no danger of pilot cracking under the head. After hardening and tempering, the pilot may be ground to size at A, and the portions B B ground to fit the hole of the counterbore. After grinding, the pilot may be forced into place. The counterbore may be ground with the pilot in position. When dull the pilot should be forced out of the counterbore and the cutting edges ground with an emery wheel.

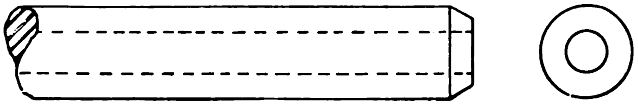


Fig. 136.

Combination Counterbores are made when it is necessary to change the size of counterbore and pilot frequently. A shank or bar is made to accommodate different sizes of cutters, and sleeves serve as pilots. In Fig. 137, A is the cutter, B the pilot which is tapped in the end to receive a screw which holds the sleeves, and C the shank which is held in a chuck or collet, when the counterbore is in use.

After taking a roughing chip off the bar, the end B is run in

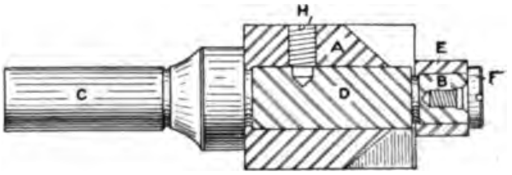


Fig. 137.

the steady rest and the hole for the screw F is drilled and tapped. The outside end is countersunk to a 60° angle to run on a center. When machining the holder, the portions B, C, and D should be left about .010 inch larger than finish size to allow for grinding. But if no grinder is at hand it may be left a few thousandths of an inch above size, and filed to finish dimensions.

The body (or cutter) A, should have a hole $\frac{1}{16}$ inch smaller than finish size drilled through it; the outside surface should be turned off, and the piece annealed. If a grinder having an internal grinding attachment is at hand, the hole in the cutter should be left .005 inch small for grinding. If such an attachment is not at hand the hole may be reamed to finish size. The outside diameter should be left about .010 large; the ends should be faced to length, and the teeth cut. If four teeth are to be cut, the work may be done with a side milling cutter as shown in Fig. 133. The counterbore should be held in a chuck on the spiral head

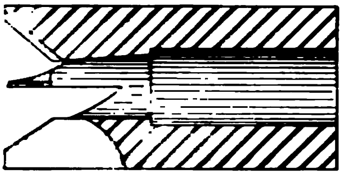


Fig. 138.

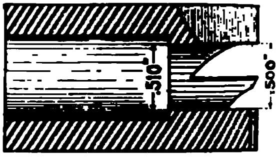


Fig. 140.

spindle, which should be tipped to produce a strong tooth as shown in Fig. 137. Before hardening, the hole should be drilled and tapped for the screw H which holds the counterbore to the bar. To harden, the counterbore should be given an even, low red heat, and plunged in water or brine in such a manner that the bath will come in contact with the teeth. If the teeth are stubbed

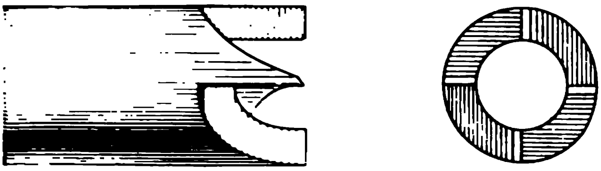
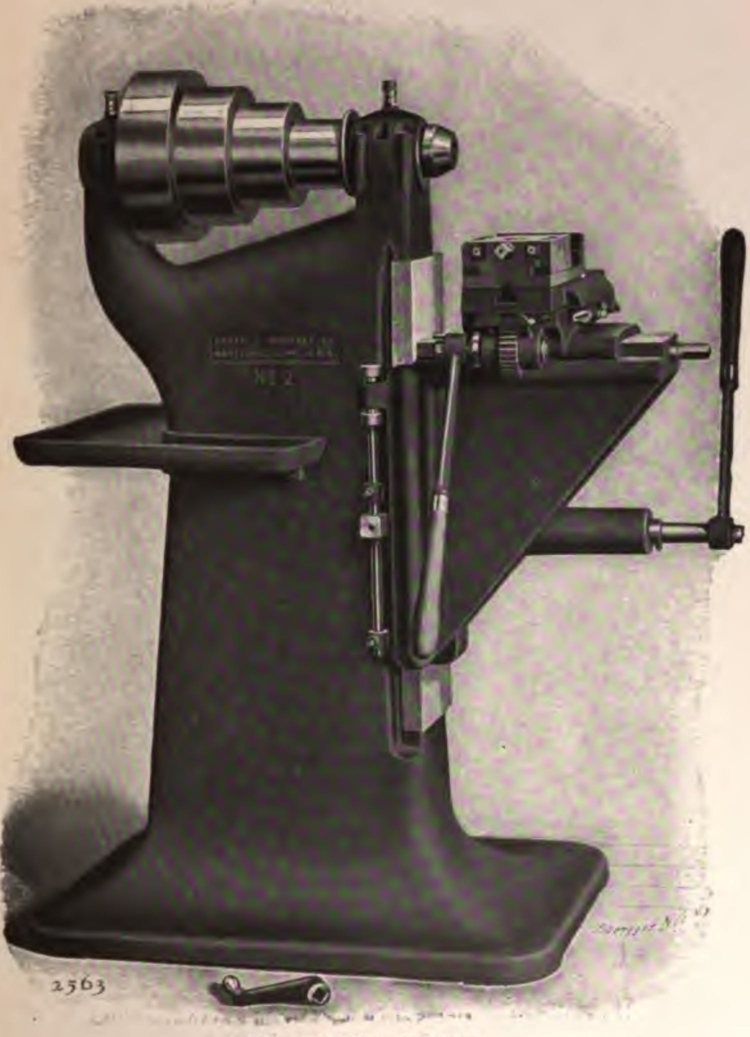


Fig. 139.

and strong the temper need not be drawn more than to a light straw color.

The screw H should be made of tool steel having a projection [illegible] one end, turned to the bottom of the thread; this is to enter a hole drilled in the bar or holder, and keep the counterbore from turning. The end of the screw should be about [illegible] smaller than the hole. The screw should be hardened and drawn to a blue color. The sleeve intended to go on the [illegible] F should be made of tool steel, hardened and ground to size inside and out. The screw F may be made of machinery steel.



HAND MILLING MACHINE.

Pratt and Whitney Co.

and case-hardened sufficiently deep by heating to a red and sprinkling with powdered cyanide of potassium, after which it is reheated and plunged in water.

HOLLOW MILLS.

Hollow mills are used in screw machines and turret lathes for roughing down and finishing. They are also used in drill press work in finishing a projection which must be in some given position; when thus used they are generally guided by a bushing in a fixture, to bring the projection in the proper location.

For roughing out work on a screw machine or turret lathe, solid mills having strong stubbed teeth are preferred for rigidity. For finishing they are made adjustable in order to get *exact* sizes. Fig. 138 shows a solid hollow mill having the cutting end hollowed out in the form of a V, in order that it may center itself when starting to cut. Fig. 139 shows a form of solid hollow mill intended for use in squaring up a shoulder at the end of a cut that has been made with a mill of the form shown in Fig. 138, or it may be used for roughing out a piece; however, it will not center itself as readily as the one shown in Fig. 138.

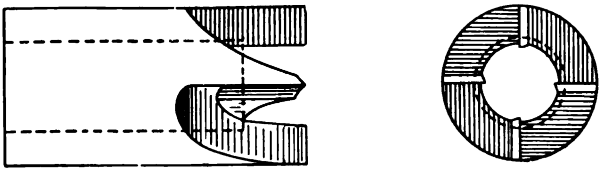


Fig. 141.

For small hollow mills some tool makers advocate three cutting teeth, while others claim better results with four teeth on all sizes.

The rear of the mill is bored somewhat larger than the cutting end, to allow it to clear on long cuts. The cutting end must be relieved or it will bind and rough the work, and probably twist it off in the mill. There are several methods of relieving mills; the more common one is to ream the hole tapering, making it larger at the back end, as shown in Fig. 140. Another method is to file back of the edges, as shown in Fig. 141.

For making hollow mills having the same outside diameter, it is advisable to use a holder of the form shown in Fig. 142, having a taper shank which fits the spindle of a lathe. The hole in the other end of the holder should be the size of the holder in the screw machine or turret lathe, which holds the mills when in use. The steel for the hollow mills should be cut to length and turned to the proper diameter to fit the holder. After putting the blank in the holder, the ends may be squared and the holes drilled and bored to the desired sizes. If the mill is to be of the form shown in Figs. 138, 139 and 140, the cutting end may be reamed with a taper reamer to give the necessary clearance. The reamer should be run in from the back end in order that this end of the hole be larger. For the form shown in Fig. 141, the hole at the cutting end should be straight and to finish size.

The mill is now ready for cutting the teeth. If four cutting edges are to be given, a side milling cutter may be used of a diameter about double the diameter of the hollow mill to be cut. The blank should be held in a chuck on the end of the spindle in the spiral head. For a strong tooth, the spiral head may be set at an angle that will produce a tooth as shown in Fig. 143, by feeding the milling cutter *through* the blank. If a deeper tooth is desired, the spiral head may be set so that the blank will be in a vertical position, and the milling cutter fed in until the desired form and depth of tooth is obtained.

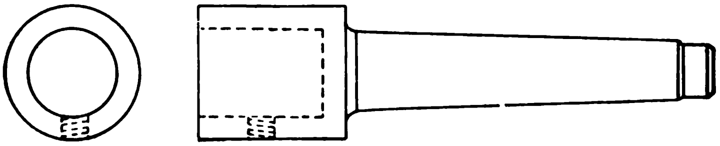


Fig. 142.

An Adjustable Hollow Mill may be made by following the instructions given for *solid* hollow mills, except that the mill must be split as shown in Fig. 144, in order that the size of hole in the mill may be altered. There are two methods of adjusting the mill: the outside of the cutting end of the mill is tapered, and a collar having a corresponding taper hole is forced on the mill. The collar closes it, and causes it to cut smaller. The other method is to turn the outside of the hollow mill straight, and close by means of the clamp collar shown in Fig. 145. As adjust able hollow mills are generally used for finishing cuts, and are not used when taking heavy cuts, the teeth may be made finer than those of solid mills used for roughing. The teeth being nearer together will finish a cylindrical piece more accurately than if the teeth were cut farther apart. It is customary to give adjustable hollow mills to be used for finishing from six to eight teeth. The cutting edges should be cut radial for most work. Better results will be obtained if the hole in the cutting end of the mill is left .005 inch small, and ground to size after the mill is hardened.

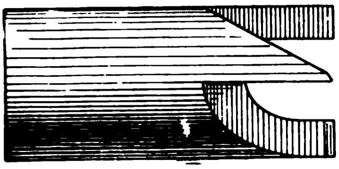


Fig. 143.

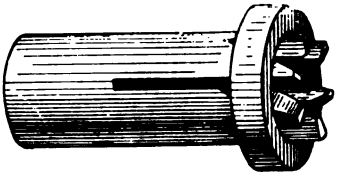


Fig. 144.

The hollow mill, whether it be solid or adjustable, should be hardened a trifle farther up than the length of the teeth, and drawn to a straw color. The mill is sharpened by grinding on the ends of the teeth.

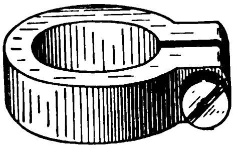


Fig. 145.

Hollow Mill with Inserted Blades. For large work, hollow mills are made having inserted blades. The hollow mill with removable blades, shown in Fig. 146, does good service on rough work; the blades may be made of self hardening steel and inserted in a machine steel body. The grooves in the body to receive the blades should be milled with a cutter whose thickness corresponds to the size of the steel to be used for the blades. The grooves are cut somewhat deeper at the front end of the holder in order that the blades may have clearance to prevent binding. The edge of the slot corresponding to the cutting edge of the blade should be radial.

Two collars should be made of machinery steel having holes sufficiently large to allow their being placed on the mill when the blades are in the slots. Each collar should be provided with the same number of set screws as there are blades in the mill. One collar holds the blades in the holder, while the other is placed nearly at the ends of the blades to support them while cutting. This

FORMING TOOLS.

Forming tools are used when several pieces are to be made of exactly the same shape. They are particularly valuable for giving the desired shape to formed mills and similar tools and are extensively used in duplicating a given shape on work produced in the screw machine.

Forming tools are made flat and circular in shape. When used in the lathe for shaping milling machine cutters and similar tools they are generally made flat; for backing off formed milling machine cutters they are always made flat; for screw machines in duplicating a given shape they are made both flat and circular.

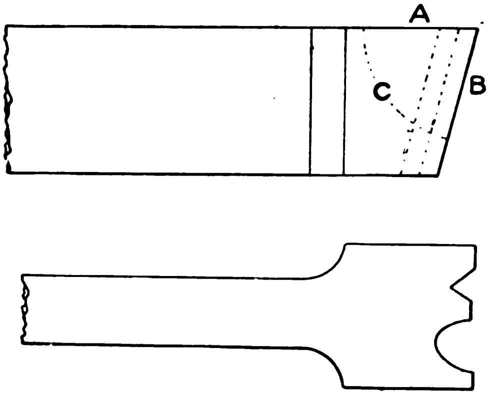


Fig. 148.

The flat forming tool is made as a solid cutter, the tool and shank being in one piece as shown in Fig. 148, or the cutter and shank may be made separate as shown in Fig. 149. When but one forming tool is to be made, that shown in Fig. 148 will be found to be inexpensive; but for making many tools, it will be found much cheaper to adopt the plan shown in Fig. 149.

On certain classes of work it is advisable to use a forming tool on a holder of the description shown in Fig. 150, which is known as a spring holder. On account of its design it may spring somewhat when used on heavy cuts, thus reducing the tendency to chatter. It is necessary to make these holders of tool steel, giving them a spring temper at point marked A. The slot

B allows the forming blade D to spring away from the work when under heavy strain. The blades may be planed up in long strips and cut off the required length. The tongue E should fit the slot O, which, with two cap screws through F and G, securely holds the blade in position.

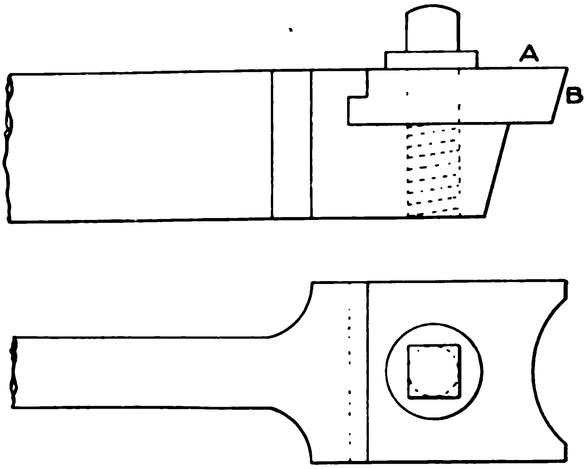


Fig. 149.

In order that a forming tool may cut readily, it is necessary to give the surface marked B a sufficient amount of clearance.

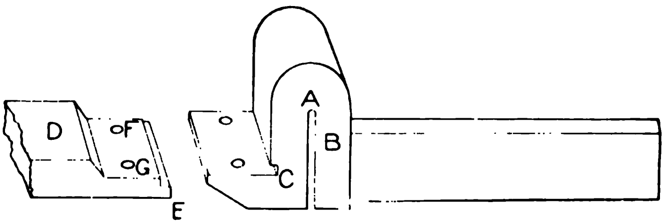


Fig. 150.

For tools to be used for shaping milling machine cutters and similar tools, a clearance of 10° to 15° will be ample; that is, the angle should be from 80° to 75°. But if the tool is to be used for backing off the teeth of formed milling machine cutters, it is necessary to give a clearance of 18° to 22°. When making a forming tool having the required angle at D, the shape can be produced by tipping the blank to the required angle and planing or milling with a tool having exactly the shape it is desired to produce. The tool used may be made of a shape enough different from that desired that it may produce the proper shape when the cutter is in a vertical position, and the blank at a given angle from that position as shown in Fig. 151. Or, the tool may be held in the tool post (or in a fixture made for the purpose) of the shaper or planer at the same angle as the blank being cut, as shown in Fig. 152, and it will produce a shape corresponding very closely with its own.

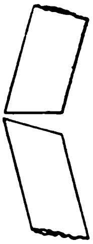


Fig. 151.

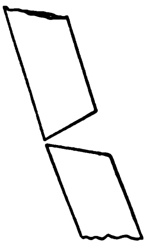


Fig. 152.

For screw machine and similar work for duplicating given shapes, a forming tool is made of the shape shown in Fig. 153. A represents a holder used by the Brown & Sharpe Mfg. Co. for use on their screw machines. B shows the forming tool blank. The desired shape is cut in the surface marked C.

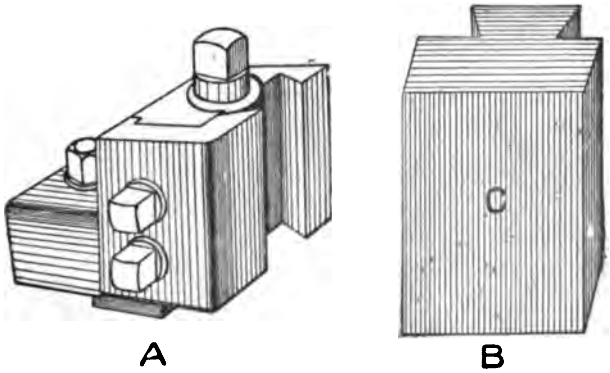


Fig. 153.

Circular Forming Tools are used very extensively on screw-machine and similar work. They are valuable on account of the ease with which any number of them may be produced, provided a forming tool is used in producing the shape on the face as shown in Fig. 154. After the blank has been formed to the desired shape, it may be milled as shown in Fig. 155 in order to provide a cutting edge. If it is desired to produce a shape on the piece being machined to correspond with the shape of tool, it is necessary to have the cutting edge radial as shown in Fig. 155. In order to feed the tool into the stock faster than can be done with the form shown in Fig. 155, it is given more clearance as shown in Fig 156. On a tool whose cutting edge is not radial and will not produce a shape corresponding to its own, it is necessary when cutting the edge with the rake shown in Fig. 156, to make the face of the tool slightly different in form from that desired.

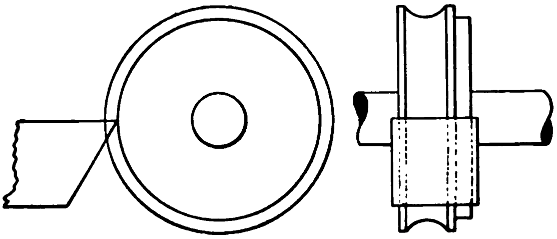


Fig. 154.

After milling the cutting edge, the name or number of the tool may be stamped on it, after which it is ready for hardening. When extremely high carbon steel is used, the tools sometimes crack while hardening from the strain incident to their shape. In order to overcome this tendency, some tool makers make two extra cuts in the edge as shown in Fig. 157, in order that the hardened edges may not be cracked from the contraction. Two cutting edges, as shown in Fig. 158 are often given tools in order that it may not need to be ground as often as when it has but one cutting edge. It is not necessary to stop the screw machine nearly as long to grind both cutting edges, as to stop the machine twice to grind the same edge on account of the time necessary to rig up the grinder.

When hardening, the tool should be heated to a low red and plunged in a bath of water or brine from which the chill has been removed; it should be worked around well in the bath. If the temper is not to be drawn after hardening, the tool may be held over the fire after removing from the bath and heated sufficiently to remove the tendency to crack from internal strains.

On account of some weak projection, which, because of its shape is likely to break when used, it is sometimes necessary to draw the temper. It is not always necessary to draw the temper to a straw color, and as a light straw is the first temper color visible, some other means must be employed. The tool may be placed in a kettle of oil, and by means of a thermometer any degree of heat may be obtained. The writer recalls a certain forming tool which was too brittle when left as it came from the hardening bath, yet was not hard enough when drawn to even the faintest straw color. When taken from the hardening bath, it was placed in a kettle of boiling water and left there about five minutes. The heat of the water at 212° reduced the brittleness

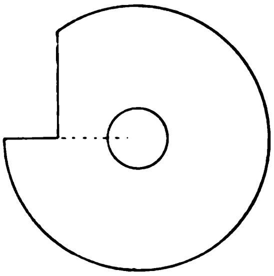


Fig. 155.

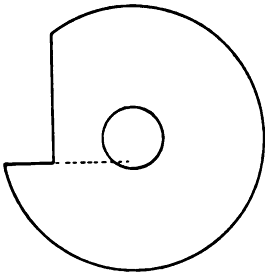


Fig. 156.

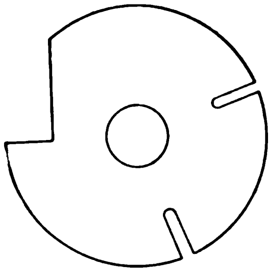


Fig. 157.

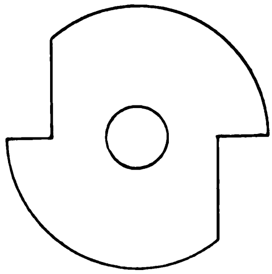


Fig. 158.

so that the tool stood up in a good shape, yet it did not perceptibly soften it.

The following is an excellent plan: Use a bath of water having about one inch of oil on top; the tool after being heated red hot is plunged down through the oil into the water. Enough oil adheres to prevent the sudden shock which the steel received when plunged into the cold bath.

"Pack Hardening" also gives excellent results.

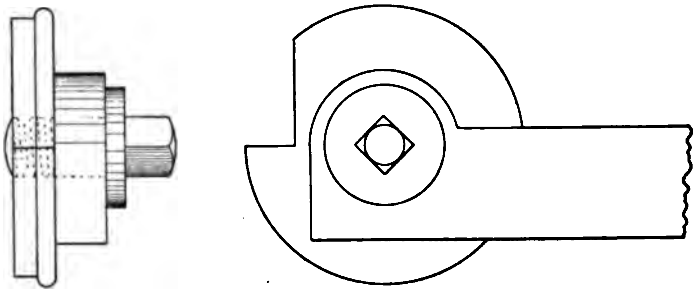


Fig. 159.

Tool Holders. The form of the holder for the tool depends on the class of work to be done and the machine in which it is to be used. Fig. 159 shows a design commonly used for hand screw machine work. If the cuts are comparatively light, the side of the tool and holder may be flat as shown. If, however, heavy cuts are taken which would have a tendency to turn the tool, it is often made with a taper projection on one side as shown in Fig. 160, the holder having a corresponding taper hole to receive the projection. This projection should be a good fit in the taper hole, but should not go in far enough to strike the bottom, neither should the side of the tool bear against the side of the holder.

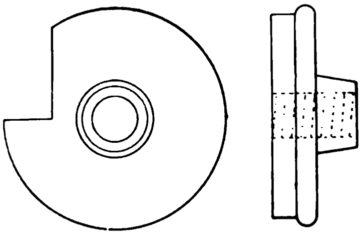


Fig. 160.

When used in automatic screw machines the holder is generally of a different shape from that used for hand screw machines.

A very common form is shown in Fig. 161. This holder is made in the form of an angle iron. The fixture (holder) is fastened to the tool rest by means of the bolt shown. The tool is fastened to the upright side of the holder by means of the bolt represented with its head let into the forming tool.

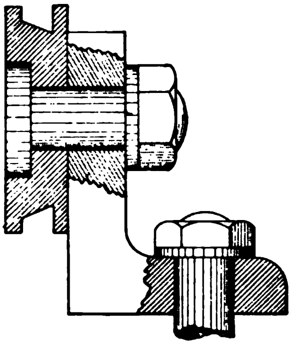


Fig. 161.

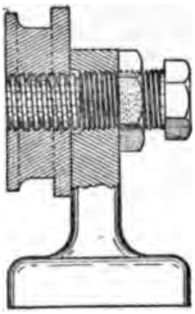


Fig. 162.

When extra heavy cuts are to be taken with a forming tool, it is sometimes considered advisable to make a holder of the form shown in Fig. 162. The holder is bolted to the tool rest in the same manner as the one represented in Fig. 161. A square thread having a pitch of five or six threads to the inch is cut in the forming tool; the thread should be right or left hand depending on which side of the machine the tool is to be located when in use, the thread being such that the tool will tighten by the pressure exerted by the cut. To get an adjustment, the thread in the holder must be of a finer pitch than that in the forming tool and of the same hand. If desired, this tool may be used in the ordinary form of holder shown in Fig. 161 by use of the bolt shown in Fig. 163.

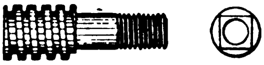


Fig. 163.

MILLING CUTTERS.

Milling machine cutters are made in two different forms: solid and with inserted teeth. It is customary in most shops to make cutters up to 6 or 8 inches in diameter solid, and above this size they are made with inserted teeth.

SOLID CUTTERS.

When making solid cutters it is advisable to use steel somewhat larger than the finish diameter of the cutter. A hole should be drilled in the blank $\frac{1}{16}$ inch smaller than the finish size of hole and the outside surface should be turned off. After annealing, it should be put in the chuck on the lathe, the hole bored and reamed to size and the hole recessed as shown at C in the sectional view of Fig. 164.

The piece should now be placed on the mandrel, and turned to the proper diameter and length. The teeth should be cut in the universal milling machine, or in a milling machine provided with a pair of index centers. The number of cutting edges for solid milling cutters varies somewhat according to the nature of the work to be done, but for general shop use the following table will be found satisfactory.

CUTTING EDGES FOR MILLING CUTTERS.

Diameter of Cutter.	No. of Cutting Edges.	Diameter of Cutter.	No. of Cutting Edges.
½	6	2½	20
¾	8	3	24
1	10 or 12	3½	26
1¼	14	4	28
1½	16	5	30
2	18	6	32

For most work it is desirable to have the faces of the teeth radial as shown in Fig. 164. However, when milling cutters are made to run in the direction of the feed or onto the work instead of against it, the teeth should be given a negative rake (cut ahead of the center) as shown in Fig. 165, as it has a tendency to keep the piece being milled from drawing toward the cutters.

When cutting the teeth, it is necessary to use a cutter that gives sufficient depth of tooth to provide a receptacle for chips, and also gives a form that supports the cutting edges. A cutter may be used that will produce an angle of about 50° between the face and back of the tooth as shown at A in Fig. 164. The cutter should cut deep enough to leave the lands about $\frac{1}{32}$ inch in width at the cutting edges.

The form of cutter shown in Fig. 164 is known as a Side Milling Cutter. When cutting the teeth on the sides, it is necessary to put the cutter on a plug whose upper end does not project much above the top face of the cutter; this plug may be made straight and held in the chuck on the end of spindle in the spiral head. Such a plug is shown in Fig. 166 inserted in the cutter. If *many* cutters are made with teeth on the sides, it is advisable to make an expanding arbor, Fig. 167, whose shank fits the taper hole in the spindle of the spiral head. When milling the teeth on the sides, the index head must be inclined a little so that the side of the mill will stand at a small angle from the horizontal in order that the lands of the teeth may be of equal width at each end. The amount of this inclination cannot readily be computed.

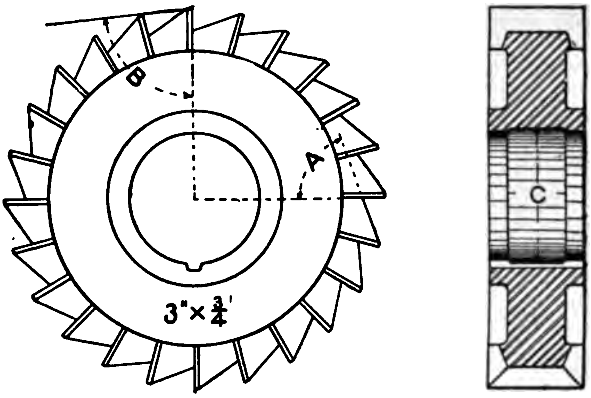


Fig. 164.

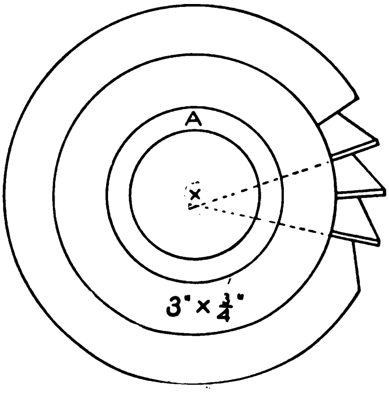


Fig. 165.

It is formed by first cutting a tooth leaving the cut somewhat shallow, then turning to the next tooth. After cutting the second tooth, the change in inclination will be apparent.

When the teeth are cut and the burrs removed, the diameter and length of the cutters may be stamped as shown in Fig. 164. The cutter is now ready for hardening. To successfully harden, it is necessary to have a *low, uniform* red heat; the teeth must be no hotter than the portion between the hole and the bottom of the teeth. When held toward the light there should be no trace of black in the interior of the cutter. When a uniform heat no higher than is necessary to harden the steel has been obtained, the cutter may be plunged into brine from which the chill has been removed; it should be worked around rapidly in the bath until the singing has ceased. It should then be removed from the brine and immediately plunged into oil and allowed to remain there until cold. When cold, the cutter may be taken from the oil and heated sufficiently to prevent cracking from internal strains. The cutter may now be brightened and the temper drawn to a straw color.

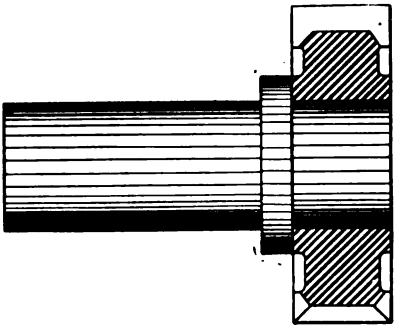


Fig. 166.

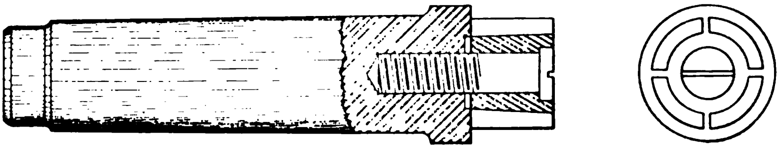


Fig. 167.

Grinding the Hole to Size. It is customary to ream the holes in milling cutters to size, and if the cutter contracts in hardening, the holes are brought to size again by lapping with a lead or cast iron lap, by means of oil and emery. However, this operation does not provide for the enlarging of the hole. While this is an unusual occurrence, it *sometimes* happens, and as a consequence the cutter does not fit the milling machine arbor and cannot do as good or as much work as it should.

On account of the necessity of having a correct fit on the milling machine arbor, it is advisable to ream the hole of the cutter with a reamer about .005 inch under the size of the arbor and finish by grinding after the cutter is hardened.

When grinding the hole to size, the cutter may be held in a chuck and ground with a small emery wheel, using the internal grinding attachment as shown in Fig. 168. This attachment is so designed that it may be swung out of the way when gauging the size of the hole as shown in Fig. 169. After grinding the hole to size it is advisable to grind the shoulders on each side of the cutter straight and true with the hole in order to prevent any possibility of springing the milling machine arbor by any untruth on the part of the cutter, and to prevent any possibility of the cutter running out of true. The shoulder (or boss) referred to is shown in A, Fig. 164.

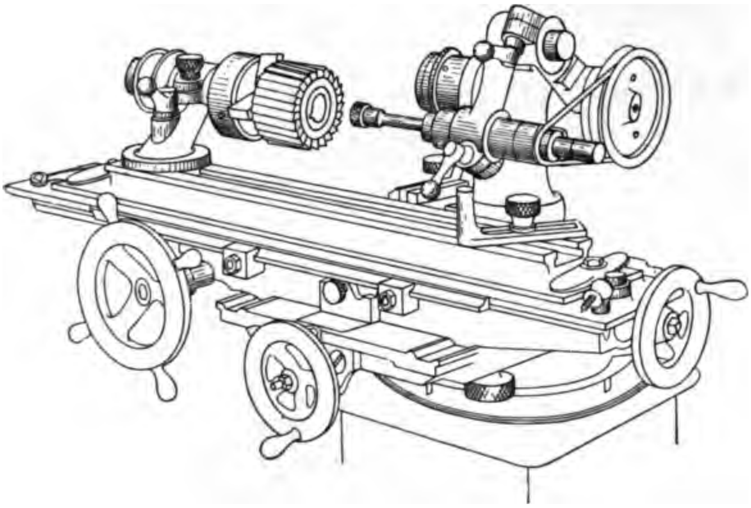


Fig. 168.

There are two methods of grinding the shoulders. By one method the outer shoulder and the hole are ground at the same setting; if this is done properly this shoulder will be true with the hole. The chuck is now removed from the grinder and a face plate having an expanding plug is put in its place. The shoulder that has been ground is placed against the face plate with the expanding plug in the hole of the cutter. The outer shoulder may be ground after the plug is expanded until the cutter is held rigidly in place against the face plate which should run perfectly true.

By the other method both shoulders are ground while on an arbor which is necked down each side of the cutter as shown in Fig. 170. This necking allows the wheel to traverse the whole length of the shoulder and not cut into the arbor, as would be the case if an ordinary mandrel were used.

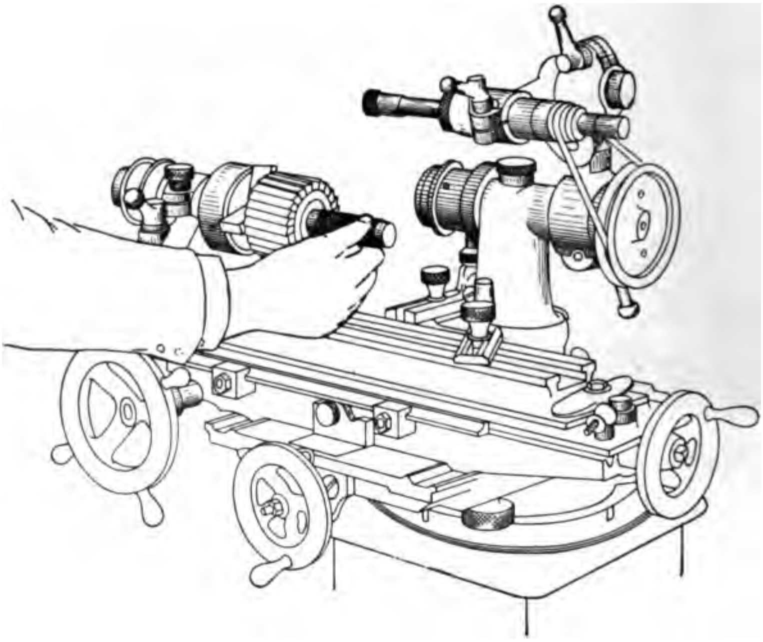
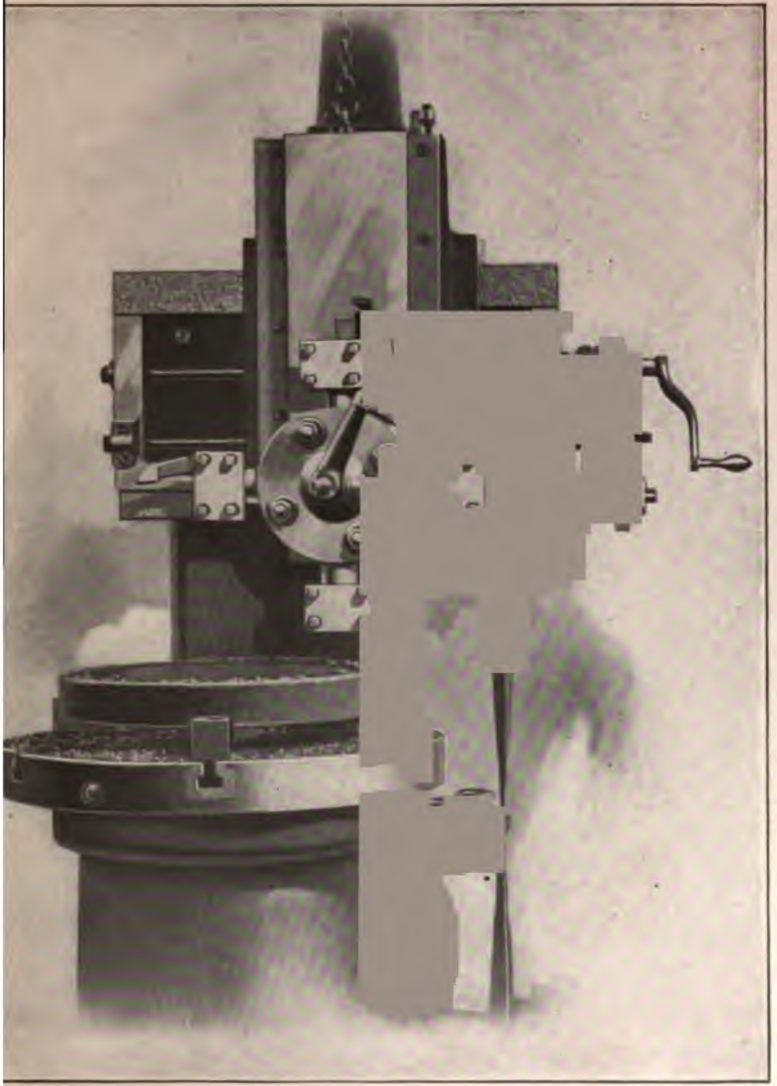


Fig. 169.

Grinding. In order to get the best results from a milling cutter it is necessary to use some form of grinder having a means of properly locating each tooth as it is presented to the wheel. This is usually accomplished by a finger which may be adjusted



BORING AND TURNING MILL.
Facing and Boring Chuck Gear Ring.
Bullard Machine Tool Co.

to the proper height to produce the required amount of clearance. The teeth may be given a clearance of about 3° as shown at B, Fig. 164. With this amount of clearance the cutter works freely and retains its edge; if more clearance is given the cutter is likely to shatter, and the edges of the teeth will become dull rapidly.

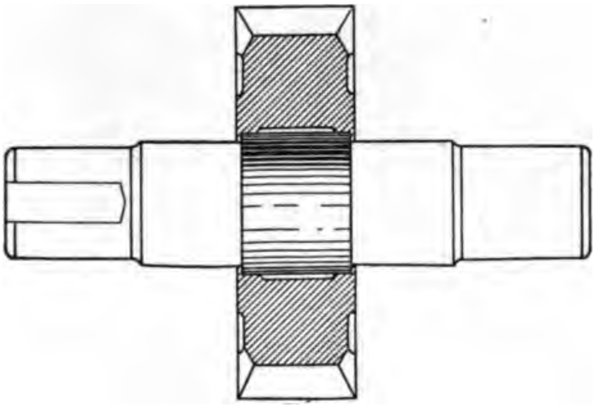


Fig. 170.

Fig. 171 shows a cutter in position for grinding the teeth; it will readily be seen that the tooth being ground rests on the finger or tooth rest; this finger may be adjusted to give any desired amount of clearance to the tooth. For grinding the teeth on the *side* of a milling cutter, a small emery wheel may be used in order to get the necessary amount of clearance without touching the tooth next to the one being ground.

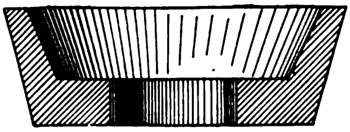


Fig. 172.

If a grinder is used which will take a cup wheel as shown in Fig. 172, and whose table can be turned to bring the cutter in the position shown in Fig. 173, a form of clearance is given the tooth which is more satisfactory than if ground with a small wheel. With the cup wheel the line of clearance is straight, while with the small plain wheel it is hollowed out, and as a consequence the cutting edge is weak.

Spiral Milling Cutters. It is customary in most machine shops to make all milling cutters of more than ½ inch face with teeth cut spirally as in Fig. 174. The amount of spiral given the teeth varies in different shops and on different classes of work.

The object of providing spiral teeth is to maintain a uniformity of cutting duty at each instant of time. With teeth parallel to the cutter axis, the tooth on meeting the work will take the cut its entire length at the same instant, causing a jump to the work on account of the springing of the device holding the work, and of the cutter arbor. If the teeth are cut spirally, the cut proceeds gradually along the whole length of the tooth, and after the cut is started a uniform cutting action is maintained, producing smoother work and a truer surface, especially in the case of wide cuts.

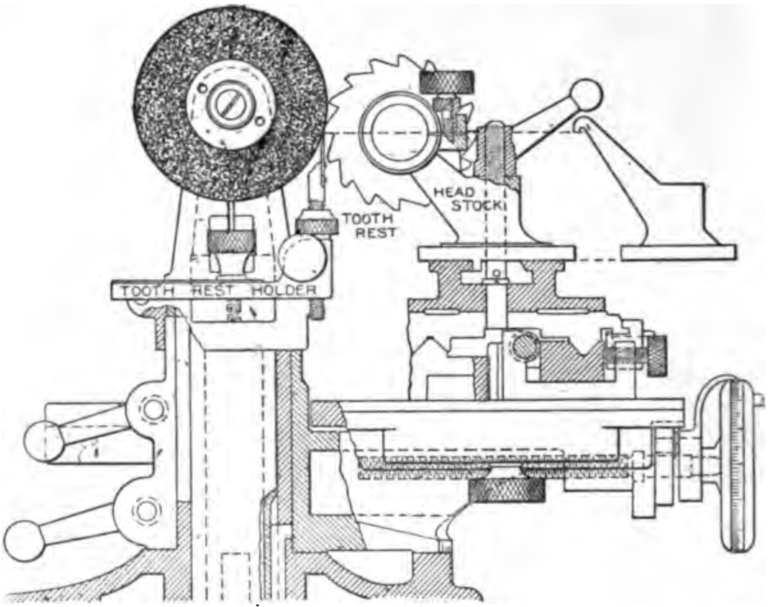


Fig. 171.

Milling cutters may be cut with either a right or left hand spiral, or helix, although it is generally considered good practice to cut a mill having a wide face with a spiral that will tend to force the cutter arbor into the spindle rather than to draw it out; then again, it is better to have the cutting action force the solid shoulder against the box, rather than to draw the adjusting nut against the box.

Where two very long mills are used on the same arbor and it is found necessary to cut them with a quick spiral, one cutter is sometimes cut with a right hand spiral and the other with a left hand spiral, in order to equalize the strain and reduce the friction resulting from the shoulder of the spindle pressing so hard against the box.

Special care should be taken in cutting spiral milling cutters that the work does not slip. When a cut has been taken across the face of a cutter it is best to lower the knee of the milling machine, thus dropping the work away from the mill while coming back for another cut; the knee can then be raised to its proper position which may be determined by means of the graduated collar on the elevating shaft of the machine.

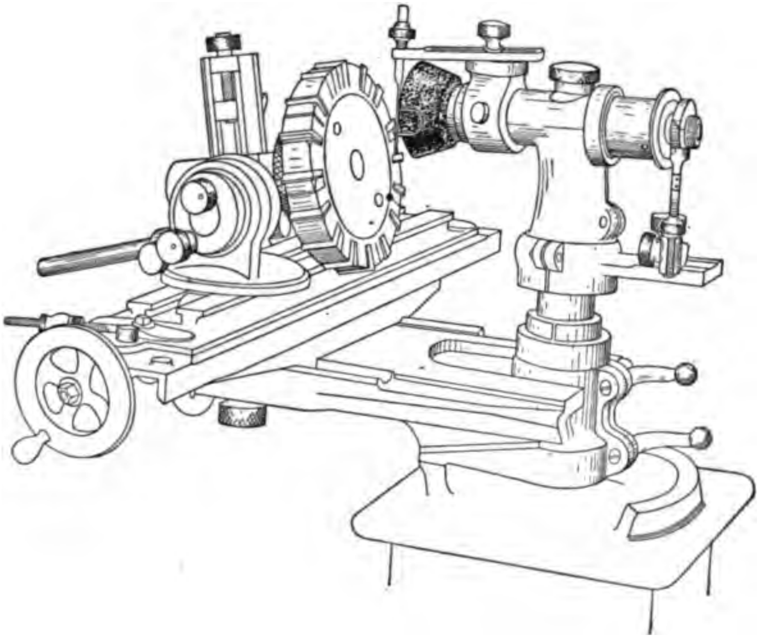


Fig. 173.

As it is important that the face of the cutting tooth be radial and straight, it will be found necessary to use an angular cutter of the form shown in Fig. 175, as cutters of this form readily clear the radial face of the cut and so remain sharp longer and produce a smoother surface to the face of the tooth than if cut with an angular cutter of the form used for cutting teeth which are parallel to the cutter axis.

The angular cutters for spiral mills are made with either 40°, 48° or 53° on one side and 12° on the other.

By setting the cutter, as shown in Fig. 175, so that the distance A is one twelfth the diameter, the face cut by the 12° side of the angular cutter will be nearly radial for the usual proportions.

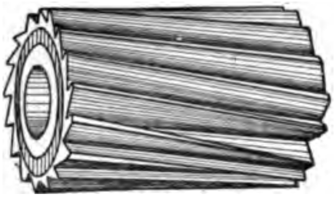


Fig. 174.

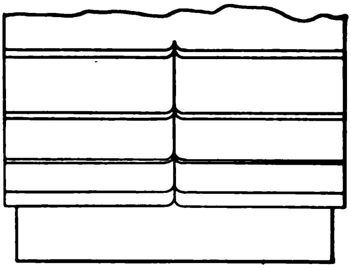


Fig. 176.

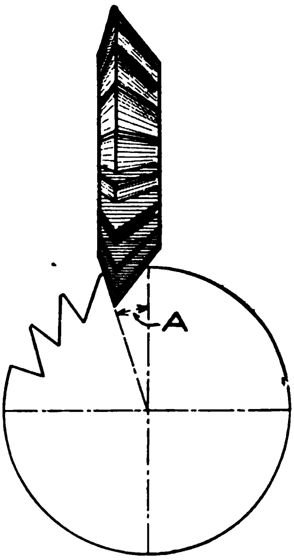


Fig. 175.

The setting for cutting the teeth of a spiral cutter must be made before turning the spiral bed to the angle of the spiral.

Milling Cutters with Interlocking Teeth. When two milling cutters of an equal diameter are to be used on the same arbor in such a manner that the end of one cutter is against the end of the other, the corners of the cutting teeth are likely to break away leaving a projection — or fin — on the work as shown in Fig. 176. In order to overcome this, part of the teeth are cut away on the sides of the cutters; that is, a tooth will be cut away on one cutter and the corresponding tooth on the other cutter will be left full length to set into the recess formed by the cutting away of the tooth. In some shops it is customary to cut away every other tooth while in others two, three or four teeth, will be cut away and an equal number left. Fig. 177 represents a pair of mills having every other tooth cut away, while Fig. 178 represents a pair having four teeth cut away.

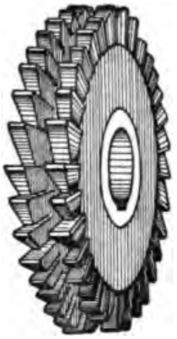


Fig. 177.

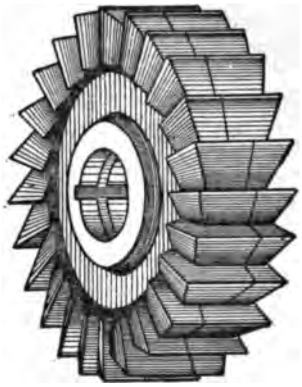


Fig. 178.

In order to cut away the teeth to make the cutter of a form having interlocking teeth, the cutter should be placed on a plug or expanding arbor as described for milling teeth on sides of side milling cutters. By means of a milling cutter having the proper width, the teeth may be milled away, although in case a cutter having several teeth cut away as shown in Fig. 178, it is well to use a narrow cutter and after taking one cut turn the index head so that the next tooth is in position. Continue doing this until the desired number of teeth are cut away. The index head may now be turned to pass over the required number of teeth and the operation repeated.

It is necessary when making cutters with interlocking teeth (sometimes called dodged-teeth) that the milling be deep enough to prevent the corresponding tooth on the other part of the cutter from striking the bottom of the recess. The parts of the cutter should bear against each other on the shoulders, or hubs.

An excellent form of milling cutter to be used for milling slots or similar work may be made as shown in Fig. 179. This form is less expensive to make than one having interlocking teeth and answers the purpose as well. It is necessary to make an eccentric mandrel of the design shown in Fig. 180 having the eccentric centers on opposite sides of the regular centers as shown. The two pieces which make the cutter should be cut from the bar long enough to finish the thickness of the heaviest part A A, Fig. 179. The hole is made $\frac{1}{16}$ inch smaller than finish size, the outside surface turned off and the pieces annealed.

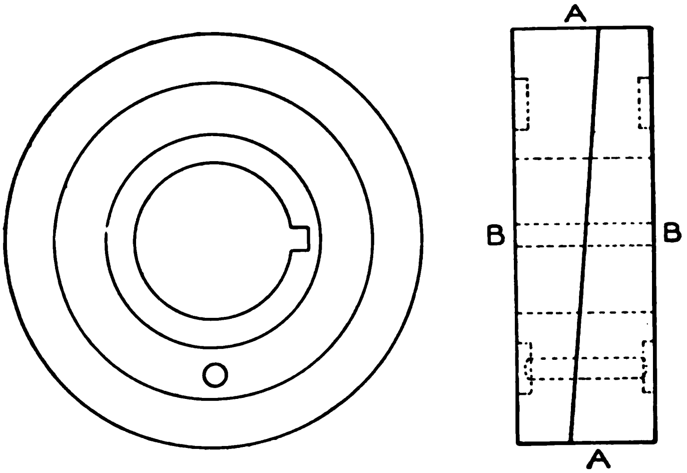


Fig. 179.

After annealing, the hole may be made the desired size for grinding. One of the pieces may then be placed on the eccentric mandrel, forcing it on until the side that is to be beveled is exactly in the center of the mandrel. The side B may be machined with the mandrel running on the regular centers while the beveled side must be machined with mandrel running on the eccentric centers. When the arbor is running on these centers, a distance half way between the two ends runs true; it is at this point that the side of the blank to receive the bevel should be located as shown in Fig. 181 provided the eccentric centers are of an equal depth. After machining the two parts of the cutter to shape, they should be so placed on a stud that the two beveled sides will be next each other as shown in Fig. 179, and the thinnest part of one next to the thickest part of the other. The pin hole may now be drilled and reamed for a $\frac{3}{16}$ inch pin which should be inserted. The blank is next placed in the vise on the shaper or planer and the spline slot cut as shown. It is now ready to be milled. After the cutter is hardened, the beveled sides may be ground true, the halves put together, hole ground to size, and the cutter ground to thickness, after which the teeth may be ground for clearance. If it is found necessary to increase the width of the slot, it may be done by shimming between the two parts of the cutter with paper or thin sheet metal; the design of the cutter allows this to be done without leaving any *fin* in the slot.

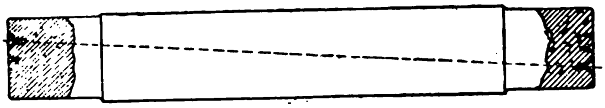


Fig. 180.

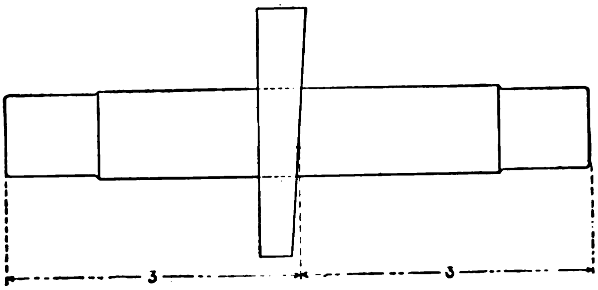


Fig. 181.

Nicked Teeth. Spiral cutters with nicked teeth, Fig. 182, are especially adapted for heavy milling. As the chip is broken up a much heavier cut can be taken than would be possible were an ordinary cutter used. The nicking may be done as follows: An engine lathe may be geared to cut a thread of the required pitch — two threads to the inch will be found satisfactory — and with a round nose tool $\frac{1}{8}$ inch wide cut a thread of sufficient depth that it may not grind out before the teeth will become too shallow to allow further grinding. This thread should be cut before milling the spaces to form the teeth.

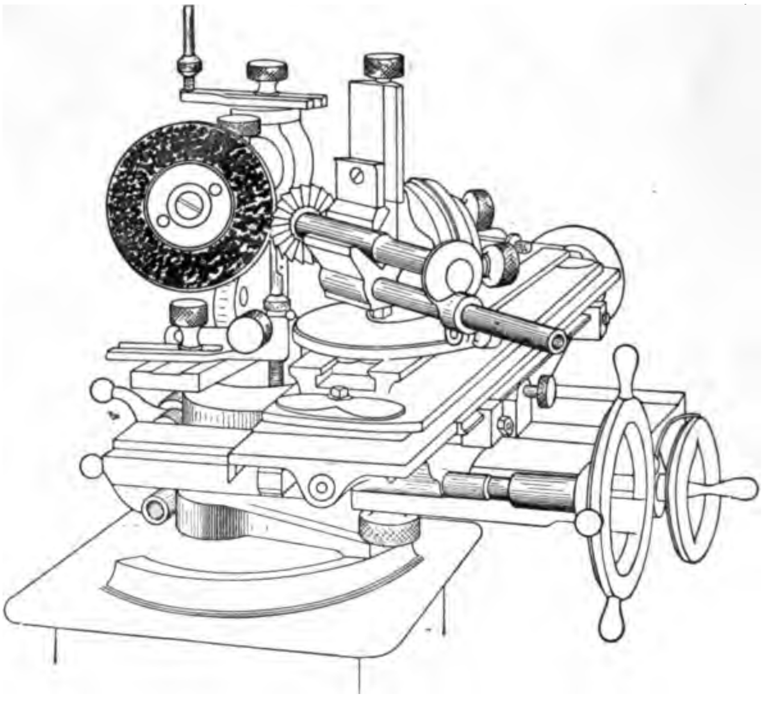


Fig. 183.

Angular Cutters. When making angular cutters the same general instructions given for making solid straight cutters should be followed except that the desired angle should be given.

When milling the spaces which form the teeth, the index head is set at an angle that will cut the edge of the tooth of an equal width its entire length. After removing the burrs the cutter may be hardened and tempered. The hole should be ground to size and the sides ground true with the hole. It should then be placed on a mandrel or stud and the teeth ground for clearance. Fig. 183 shows the method used in grinding the teeth of a mill of this form.

MILLING CUTTERS WITH INSERTED TEETH.

When milling cutters exceed 6 or 8 inches in diameter, it is generally cheaper to make the body of cast iron or machinery steel and insert in the periphery teeth made of tool steel. There is a variety of methods for holding the teeth in place. If the cutter is narrow, or is to be used as a side milling cutter, the grooves to receive the teeth may be cut straight (parallel to the cutter axis) as shown in Fig. 184. If the cutter face is over one inch long, the slots to receive the teeth should be cut in such a manner that spiral teeth may be used.

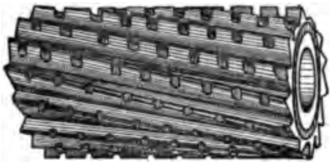


Fig. 182.

While it is a comparatively easy matter to cut the slots spirally, it is difficult to make the teeth of a shape that will fit the spiral slots without the aid of special tools. Consequently the slots are generally milled at an angle to the cutter axis, having the side of slot that corresponds to the face of the tooth equidistant from a radial line at each end of the cut. The face of the

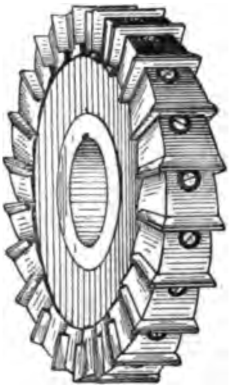


Fig. 184.

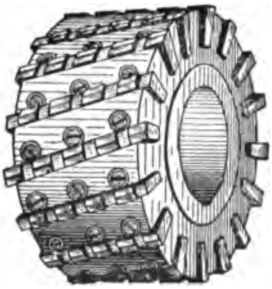


Fig. 185.

slot at one end would be ahead of the center, while at the opposite end it would be behind the center; this is termed a front rake, and a negative rake respectively.

The slots should be cut somewhat wider than would be necessary were the teeth to be made of a spiral form. After turning to size, the faces of the teeth may be milled spirally to make them radial.

If the mills are intended for heavy work, the teeth may be nicked as already described. The coarse pitch thread should be cut before the teeth are milled spirally.

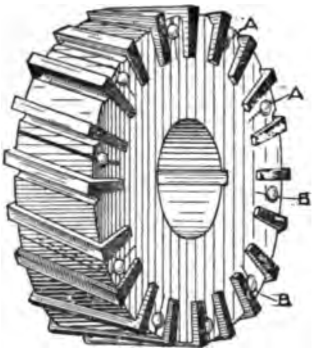


Fig. 186.

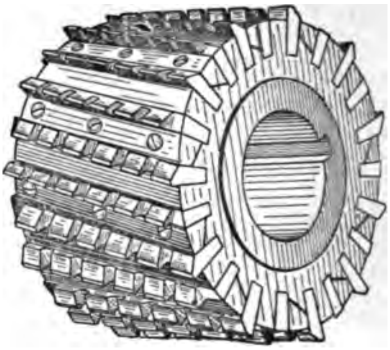


Fig. 187.

After hardening, the teeth may be put in place and fastened; they are now ready for grinding. The emery wheel for grinding milling machine cutter teeth should be of the proper grade as to hardness and coarseness; if the wheel is very *hard* or *fine*, it will be likely to draw the temper at the cutting edges of the teeth; the emery should not be coarser than No. 60 or finer than No. 90.

If the face of the wheel is glazed, remove the glaze with a piece of emery wheel somewhat harder than the wheel in use; this not only removes the glaze but makes the surface of the wheel more open and less likely to glaze. The emery wheel should run *true;* its face should not exceed $\frac{1}{4}$ inch in width. Generally speaking, the softer the emery wheel the *faster* it should run, but the peripheral speed should not exceed 5,000 feet per minute.

Fastening. There are several methods for fastening the teeth in this form of cutter, any one of which gives satisfaction if the work is well done.

The method illustrated in Fig. 186 is in use in the works of the Pratt and Whitney Co., of Hartford, Conn. In this design, between every second pair of teeth a hole is drilled and reamed taper to receive the taper pins A A, after which the slots B B are cut with a thin cutter. After the cutters are in place the taper pins A A are driven into the holes, thus locking the cutters. To remove the cutters the pins are driven out.

A method of fastening the cutters which are used by the Morse Twist Drill & Machine Co., of New Bedford, Mass., is shown in Fig. 187. In this case the stock between every second pair of teeth is milled away not as deep, however, as the slots for the cutters. Wedge-shaped pieces of steel are fitted between the teeth as shown. When these are drawn to place by means of fillister headed screws they bind the cutters very securely. If the wedge-shaped binding blocks touch the bottoms of the slots they will not hold the cutters securely in place.

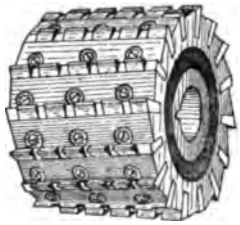


Fig. 188.

The method shown in Fig. 188 is used by Brown & Sharpe Mfg. Co. of Providence, R. I. The teeth are held in place by taper bushings and screws as shown.

Standard Key Ways. To prevent milling machine cutters turning on the arbor when cutting, it is necessary (especially when taking heavy cuts) to have key ways cut as shown in Fig. 189.

The arbor, of course, must have a similar slot to receive the key. It will be noticed that the dimension D refers to the diameter of the *hole* in cutter, and not to the diameter of the *cutter*.

Formed Cutters. As used by the Brown & Sharpe Mfg. Co., the term "Formed Cutter" applies to the cutters with teeth so relieved that they can be sharpened by grinding without changing their form. However, the term " Form Cutter " can be applied to any cutter cutting a form regardless of the manner in which the teeth may be relieved. Fig. 190 represents a formed cutter.

Formed cutters are used in many shops where work of irregular shape is milled in large quantities, as in sewing machine, gun and bicycle shops.

While this style of cutter can be made to better advantage in a shop equipped with machinery designed especially for this class of work, an ordinary engine lathe can be converted to a *backing-off lathe* for relieving or backing off the cutters. Or, a comparatively inexpensive fixture (known as the Balzar backing-off device) may be used. However, a simple arrangement consists of an eccentric arbor operated by a hand lever, or a stud may be screwed in the faceplate of a lathe; the cutter is placed on this stud in a position that allows the teeth to be given the necessary amount of clearance. When backing off the teeth of cutters whose faces do not exceed 1 inch in width the Balzar backing-off fixture shown in Fig. 191 can be used to advantage. This device

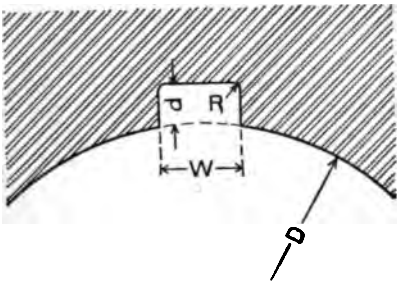


Fig. 189.

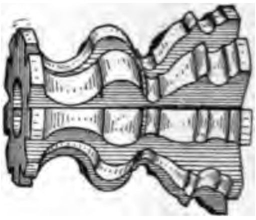


Fig. 190.

STANDARD KEY WAYS FOR CUTTERS.

Diameter (D), Inches.	Width (W), Inches.	Depth (d), Inches.	Radius (R), Inches.
$\frac{3}{8}$ to $\frac{9}{16}$	$\frac{3}{32}$	$\frac{3}{64}$	.020
$\frac{5}{8}$ to $\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	.030
$\frac{15}{16}$ to $1\frac{1}{8}$	$\frac{5}{32}$	$\frac{5}{64}$	.035
$1\frac{3}{16}$ to $1\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{32}$	.040
$1\frac{7}{16}$ to $1\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	.050
$1\frac{13}{16}$ to 2	$\frac{5}{16}$	$\frac{5}{32}$	.060
$2\frac{1}{16}$ to $2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	.060
$2\frac{9}{16}$ to 3	$\frac{7}{16}$	$\frac{3}{16}$	.060

is held between the centers of a lathe in the ordinary manner, the backing off being such that the cutter can be ground without alteration of shape. The tool is so constructed that it is only necessary to place the cutter upon the arbor in the ordinary way. Place the arbor on the lathe centers as shown, start the lathe and feed the forming tool in by the cross-feed screw in order to take

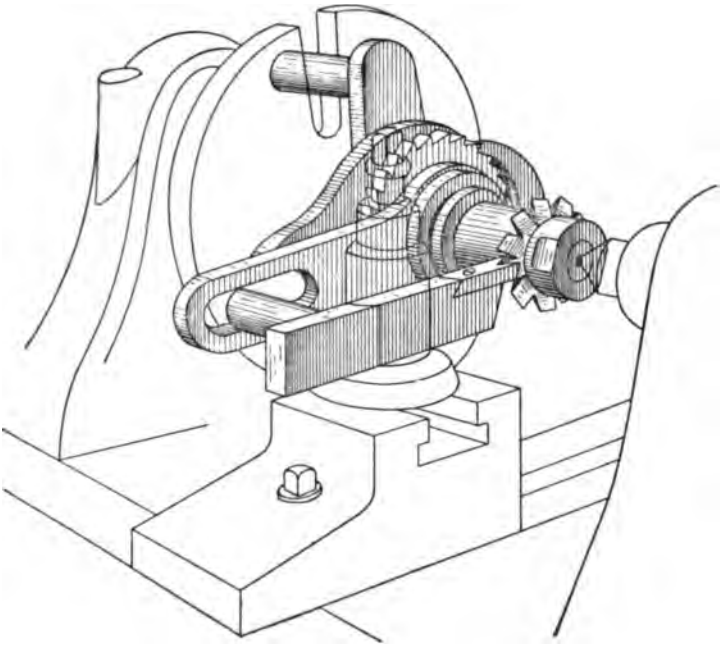


Fig. 191.

the desired cut in the same manner as in plain turning. The ratchet connected with the arbor, and actuated by the pawl, contains ordinarily thirty-six teeth and the stroke can be set to back off a cutter with 9, 12, 18 or 36 teeth.

Backing off by an Eccentric Arbor. An arbor may be made having a pair of centers located to give the cutter tooth the required amount of clearance; such an arbor is shown in Fig. 192. The eccentric centers are shown at the sectional portions at the ends. The amount of eccentricity depends somewhat on the size of the cutter to be backed off; but for cutters not exceeding 4 inches diameter, from $\frac{3}{16}$ to $\frac{1}{4}$ inch will give excellent results.

The screw at the end of the arbor should be of a fine pitch; about 12 threads per inch for arbors 1 inch diameter. The object in cutting a fine pitch thread is, the cutter being backed off may be held more securely with the same amount of power exerted in tightening the nut; again the depth of thread is not as great as for a thread of coarser pitch, and as a consequence, the plane portion at the end of the arbor (which is made the size of the bottom of the thread) may be left large enough to get in a center hole of good size having $\frac{1}{4}$ inch eccentricity.

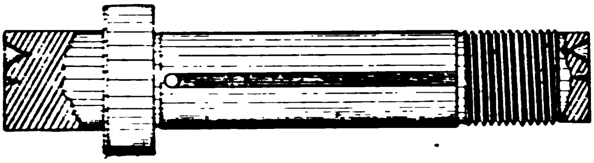


Fig. 192.

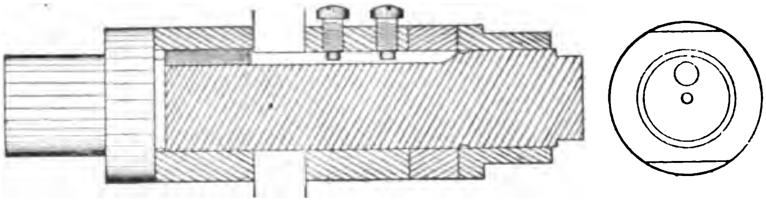


Fig. 193.

The spline cut should be at least $\frac{1}{8}$ inch wide and about $\frac{1}{8}$ inch deep; the walls of the cut should be parallel in order that the screws shown in Fig. 193 as passing through the collar and entering the slot in the arbor, may have a good bearing. These screws are to keep the collar from turning when the necessary power is applied to the nut when fastening the cutter in place. The collar on the opposite side of the cutter has a spline cut the same width as cut in the arbor, and is held in position by a spline as shown. The cutter cannot be held by a spline as it is necessary to move it each time a tooth is brought into position for backing off.

When machining the cutter blank, it is given the desired shape by means of a forming tool. If the shapes vary much in size the shape may be roughed out before using the forming tool. After it has been machined to the desired size and shape, it may be placed between the centers of the milling machine, and a number of grooves cut the entire length of the cutter. The number of grooves must correspond to the number of teeth the mill is to have; these grooves cannot be cut to finish width until after the teeth are backed off, because the forming tool cuts a trifle deeper at the point of contact, making it necessary to mill a small amount from the face of the tooth after backing off. The grooves are sometimes cut with a thin milling cutter, or a metal slitting saw $\frac{1}{8}$ inch thick. When a groove of this description is cut, the cutter has the appearance shown in Fig. 194. Cutting a groove of this form makes more work for the operator than when cut as shown in Fig. 195, in which the distance across the tops of the teeth is decreased by using an angular cutter of the shape shown in Fig. 196. After cutting the grooves the cutter may be placed on the eccentric arbor which is held between the centers of the lathe in the ordinary manner. A forming tool that will produce the desired shape of tooth is placed in the tool post; the top face of the tool must be set at the exact height of the center of the lathe in order to produce the proper shape. Fig. 197 shows an eccentric arbor

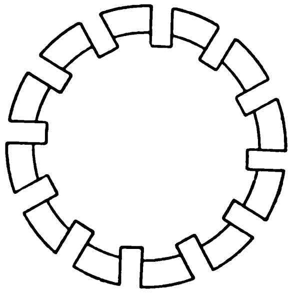


Fig. 194.

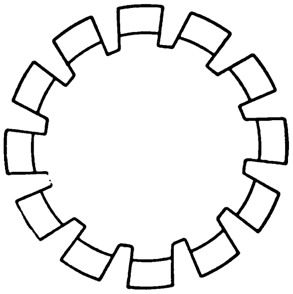


Fig. 195.

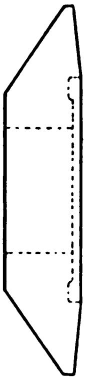


Fig. 196.

in a lathe in position to back off the teeth of a formed mill. The arbor is operated by means of the lever. The arbor is entirely independent of the spindle in its action, the eccentric centers being placed on the centers of the lathe, and the necessary motion given by means of the lever which strikes the carriage at the end of the stroke. In order to avoid bruising the lathe a strip of leather is attached to the lever as shown.

To set the cutter tooth in the proper location before backing off, a piece of thin sheet metal is placed on the top face of the tool, as shown in Fig. 198. The lever is brought down on to the carriage, the tooth of the cutter is brought down on to the sheet metal and the nut tightened. The tooth to be backed off is the one below that set to the thickness of the strip above the tool. The object in raising the tooth a given distance above the face is to prevent the one being backed from and striking the tool at the end of stroke. Again the teeth are set alike. This operation must be repeated for the setting of each tooth before backing off. The forming tool is fed by means of the cross-feed screw, a tooth

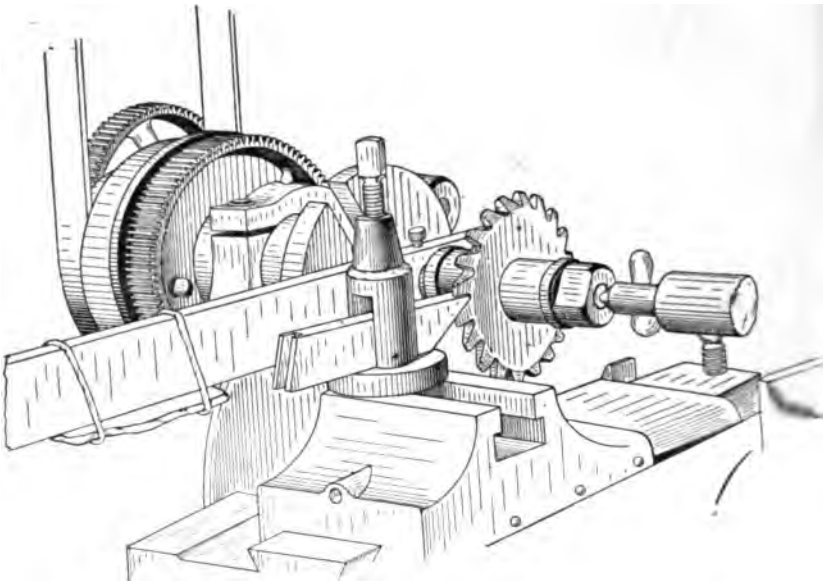


Fig. 197.

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ASTOR, LENOX AND
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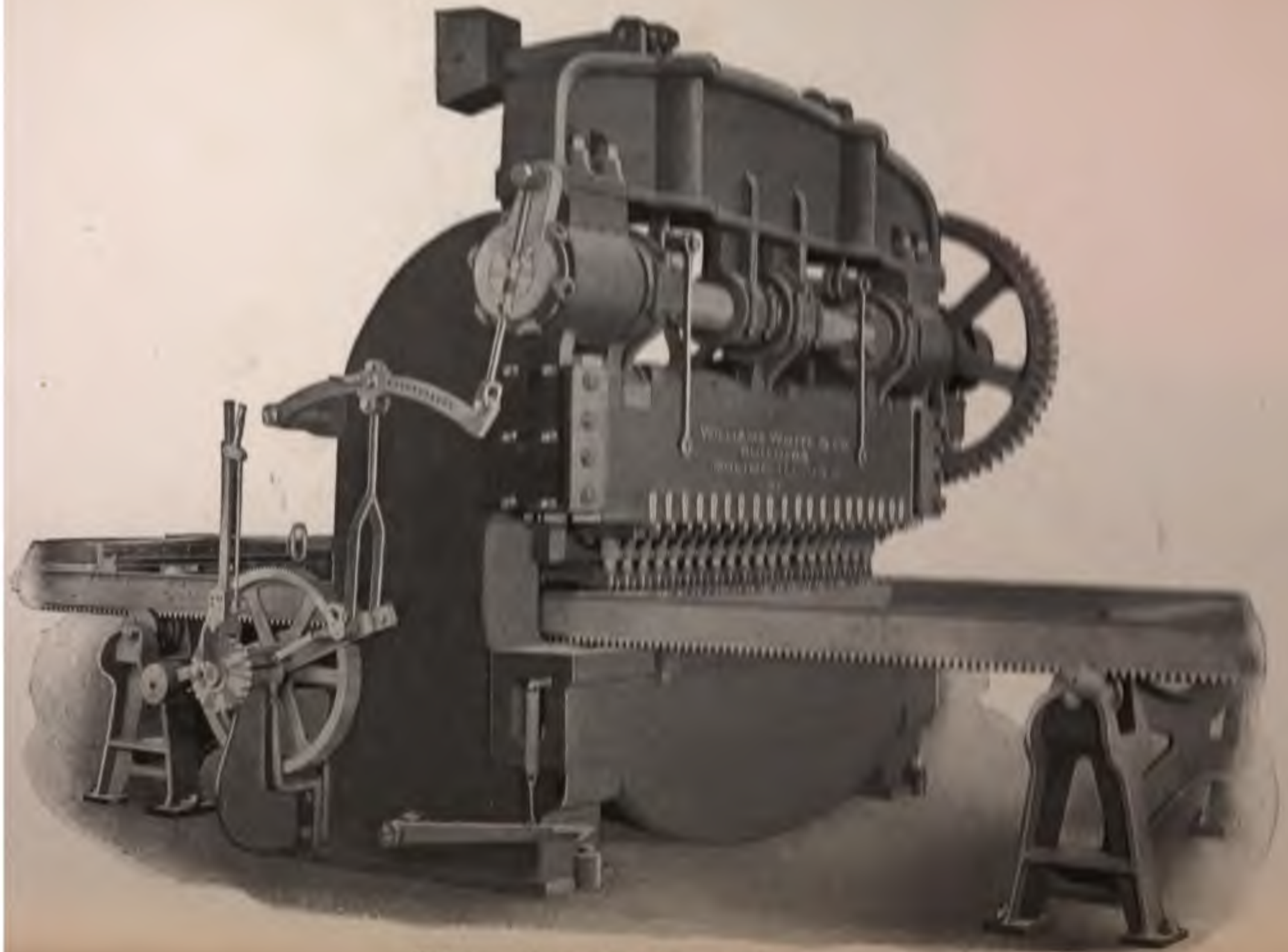

MULTIPLE PUNCHING AND SHEARING MACHINE

is backed off nearly the desired amount leaving a little for a finish cut; the tool is withdrawn, the nut loosened and the cutter turned on the arbor to bring the next tooth in position to be backed off. This operation may be repeated until all the teeth are backed off alike. The amount of backing off must be determined by the cross-feed stop, or a graduated dial on the cross-feed screw. After the roughing cut has been taken on all the teeth, the forming tool may be sharpened by grinding, or by oil stoning, and the finish cut taken on the teeth. Another method of backing off cutter teeth is shown in Fig. 199. A stud is screwed in the faceplate of a lathe near the outer edge as shown. The cutter which must be a fit on the stud is clamped by means of the nut shown. The finger A is movable in the slot in the stationary block B which is located on the face plate to bring the tooth to be backed off in its proper location, and keeps it from turning when being operated on. The forming tool is fed in gradually until the tooth is formed. The finger is then disengaged from the space in the cutter, which is revolved by means of the set screw until the next is in position.

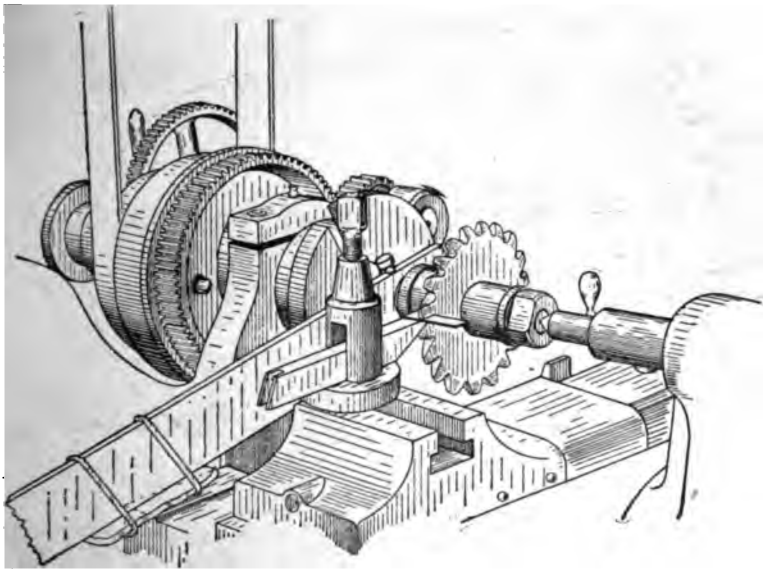

Fig. 198.

Each tooth is machined seperately, that is, the forming tool is fed in the required distance for each tooth when it is in position. The cutter is turned until the next tooth is in position, and the process repeated until each tooth has been backed off.

In backing off cutters in this device it is necessary to cut the notches (spaces between the teeth) somewhat wider than the teeth.

When backing off the teeth for clearance by any of the means described, it is first necessary to form the blank, then gash it or cut the notches as described; the teeth are now backed off.

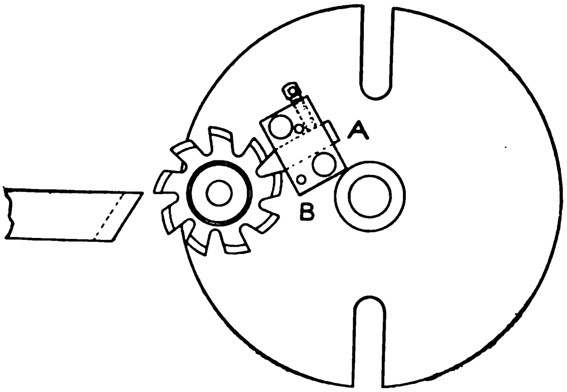

Fig. 199.

After backing off it is necessary to mill the face of the tooth back $\frac{1}{32}$ inch or so to cut away "the jump" (as it is termed) caused by the forming tool drawing in a trifle when it first strikes the edge of the tooth.

Threaded Holes. It is often necessary to make milling cutters with threaded holes. This happens in the case of *small* angular cutters, and many styles of cutters for use on profiling (edge milling) machines.

The same general instructions for making the other forms of cutters apply to those with threaded holes, except that instead of reaming the hole to a given size the thread is cut with a tap of the proper size and pitch or it is chased in the lathe. After threading, the cutter should be screwed on to a threaded arbor.

Fig. 200 shows an arbor of this description. The end A is threaded slightly tapering for short cutters about .002 inch in 1 inch of length. On the taper end of the arbor a thread should be cut of a size that will not allow the cutter to screw on the arbor quite the entire length, that is, the cutter should overhang the threaded portion of the arbor a trifle (say one thread); this allows the outer end to be squared up without mutilating the threads on the arbor. The reason for using the *taper* end of the arbor when squaring the first end of the cutter is that the shoulder is true with the thread in the cutter. After squaring this shoulder, the cutter blank may be removed and placed on the opposite end of the arbor with the side that has been squared against the shoulder of the arbor. This method of machining pieces of work having a threaded hole, where it is desirable that the outer surfaces be true with the hole, is applicable to all classes of work. The cutter may be machined to length and shape on the straight end of arbor.

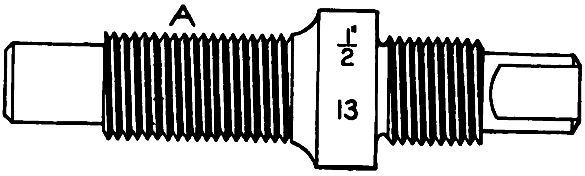

Fig. 200.

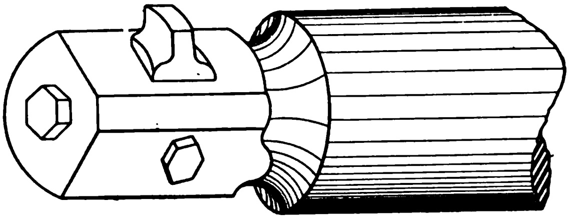

Fig. 201.

Fly Cutters. The simplest form of milling machine cutter is known as a fly cutter. It has only one cutting edge but is particularly valuable when making but one or two pieces of a kind for experimental work, and when making and duplicating screw-machine and similar tools of irregular shape.

As these cutters have but one cutting edge, they produce work very accurate as to shape, but cut very slowly and do not last as long as those having more teeth. However, they are used on *special work* on account of the small cost of making. It is necessary to hold the cutters in a *fly cutter arbor* which is shown in Fig. 201.

The cutter to be used in a fly cutter arbor may be filed to a templet, giving the necessary amount of clearance in order that the back edge, or keel, may not drag. If it is desirable to make the impression in the fly cutter with a milling cutter of the regular form, the piece of square steel from which the cutter is to be made may be held in the milling machine vise and the shape cut with the milling cutter. The desired amount of clearance may be given by holding the piece in the vise at an angle of a few degrees.

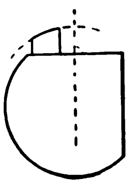

Fig. 202.

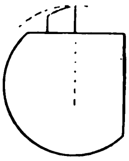

Fig. 203.

To make a fly cutter from a forming tool, the piece of steel may be held in the fly cutter arbor in such a position that the face is somewhat back of a radial line as shown in Fig. 202. After hardening the cutter may be set so that the cutting edge will be radial and the clearance will be as shown in Fig. 203.

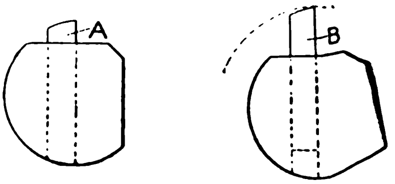

Fig. 204.

Another method of getting the clearance for the cutter is to place the top of the cutter blank as near the arbor as possible and then cut the desired shape. If the cutter is set in the arbor so that it projects from the surface it will have the necessary clearance as shown in Fig. 204. A represents the position of the blank while being cut and B the cutter in position for cutting; the dotted line showing the circle through which the cutting edge travels, the amount of clearance is apparent.

End Mills. This form of milling machine cutter (Fig. 205) is familiarly known as a **shank mill.** The term is used on account of the shank B which in small milling cutters fits into a collet. This collet in turn fits the hole in the spindle of milling machine. The collet referred to is used to save stock in making the cutters as otherwise it would be necessary to use steel large enough to make a shank of the size of hole in the spindle of the milling machine.

The cutter shown in Fig. 205 is what is termed a *left hand* mill; if the teeth run in the opposite direction, it is called a *right hand* mill.

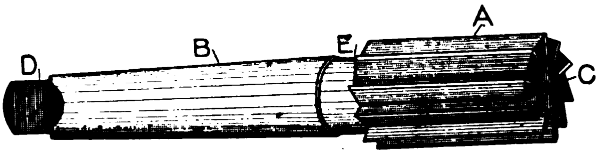

Fig. 205.

In making a shank (or end) mill of the form shown in Fig. 205 stock should be selected enough larger than the cutting end A to allow of turning off the decarbonized surface of the steel. After facing the ends to length, and turning the roughing chip, the end A may be run in the steady rest of the lathe and the center cut away — or recessed — as shown at C. The blank should be recentered and countersunk to furnish a center to use in turning the mill to size and shape. The object in cutting the center out as shown is to furnish a cavity for the angular cutter used in cutting the teeth on the end of the mill. Without this it would be impossible to grind satisfactorily.

After recentering the end C, the tenon D may be turned to size and milled to thickness, which should be a trifle ($\frac{1}{32}$ inch) less than the width of the center key slot in the collet. The taper at B should be turned enough larger than finish size to allow for grinding after the milling cutter is hardened. The cutter end A should be turned .010 inch larger than the required diameter. The portion E should be turned $\frac{1}{32}$ inch smaller than the large end of B or to dimensions if any are given on the drawings.

In order to insure teeth strong enough to resist the strain of cutting, an angular mill should be selected that will give the required shape. In Fig. 206 is shown a form of cutter tooth too weak for actual service; this tooth is the result of using an angular cutter with a cutting face forming an acute angle with the side. Fig. 207 shows a cutter whose teeth are strong, yet deep enough to be practical; these teeth were cut with an angular mill of less angle. Fig. 208 represents a cutter whose teeth were cut with the same cutter used for Fig. 206. The teeth were cut to the required depth first; this of course leaving them too thick at the cutting edges as shown in Fig. 209. After cutting the teeth as shown at A, Fig. 209, the index head was turned sufficiently to cut the teeth as shown at A, Fig. 208.

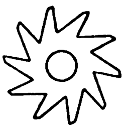

Fig. 206.

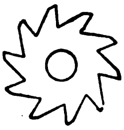

Fig. 207.

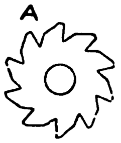

Fig. 208.

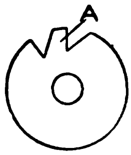

Fig. 209.

After cutting the teeth around the circumference of the mill, it should be placed in the collet and the collet put in the spindle hole in the spiral head in order to cut the teeth on the end.

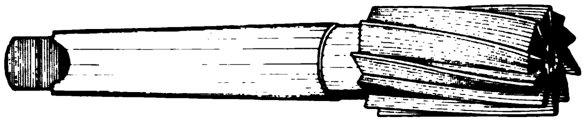

Fig. 210.

When cutting the teeth on the end of the mill, the spiral head is turned until the cutter is in a horizontal position. The angular cutter used should not have a very acute angle or the teeth will be weak. An 80° angular milling cutter will be satisfactory.

Spiral End Mills. It is sometimes advisable to cut the teeth of end mills spirally as shown in Fig. 210. As there is no support at the outer end of this form of mill it will be necessary to cut the teeth of a spiral that will have a tendency to force the mill into the collet rather than draw it out. Fig. 210 represents a left hand end mill cut with a right hand spiral.

End Mills with Center Cut. This form of End Mill is useful when it is necessary to cut into the work with the end of the mill, and then move along as in dies, cams, and grooves. The teeth being sharp on the outside, cut a path from the point of entrance. The coarser teeth allow a heavier cut, especially in cast iron. Fig. 211 shows two views of an end mill with center cut.

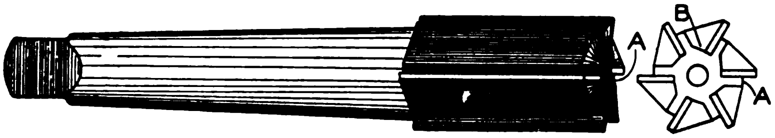

Fig. 211.

After cutting the teeth on the end with an angular cutter, a thin straight faced cutter of small diameter should be run through close to the face of the cutter tooth making a cut as shown at A; this cut should be of sufficient depth to permit of backing off the inner edge of the tool as shown at B. This clearance allows the mill to cut away the slight projection left in the center of mill when it is fed into a piece of work. Such a projection is shown at A in Fig. 212.

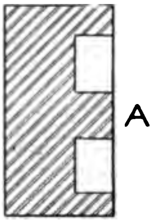

Fig. 212.

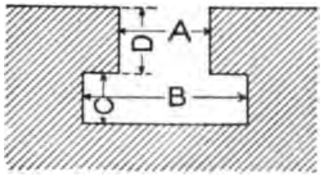

Fig. 213.

T-Slot Cutters. In cutting T slots in various parts of machines, such as milling machine carriages, etc., it is necessary to use a form of shank mill known as a T-Slot Cutter. Fig. 213 shows the ordinary form of T-slot; while Fig. 214 shows the cutter. A portion of the stock below the teeth is cut away as shown at A A in the sectional view Fig. 215. This is necessary in order to back off the teeth on the sides of the cutter for clearance, and to do away as far as possible with unnecessary friction when the cutter is working.

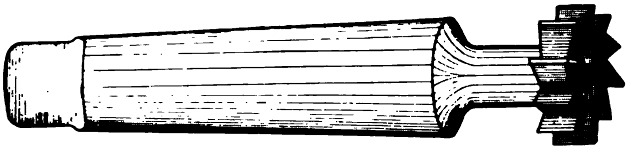

Fig. 214.

T-slot cutters are usually made $\frac{1}{32}$ inch larger in diameter than the size designated on the cutting portion to allow for sharpening; that is, a mill intended for cutting a slot $\frac{1}{2}$ inch wide is made $\frac{1}{2} + \frac{1}{32}$ or $\frac{17}{32}$ inch diameter, unless intended for cutting a slot to given dimensions.

It is advisable to harden mills of this description the entire length of the neck, especially if the neck is of small diameter; otherwise they will be very likely to spring when in use. After hardening, the neck should be drawn to a blue color, while the cutting part should be drawn to a straw color.

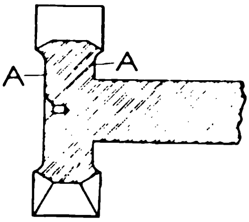

Fig. 215.

When grinding end mills, the shank in all cases should be ground first to fit the collet or holder, allowing it to enter *far enough* to key out readily, yet not enough to allow the shoulder above the tenon to strike the shoulder in the collet.

After grinding the teeth for clearance on the diameter, the teeth on the end should be ground. Most universal and cutter grinders are provided with a fixture for holding the mill by the shank while grinding these teeth; such a fixture is shown in Fig. 216.

Face Milling Cutters. This form of cutter is used in milling surfaces too large to be cut with the ordinary form of milling cutter held on an arbor passing over the work. As the full diameter of the face of the cutter may be used, it may have less than one half the size that would be necessary for a side milling cutter. A side milling cutter must be double the diameter of the surface to be cut plus the diameter of the collar on the arbor. For instance if a surface as A, Fig. 217, were to be milled, it would be necessary to use a cutter somewhat larger in diameter than twice the height of the surface plus the diameter of collar B. Whereas if a *face* milling cutter of the form shown in Fig. 218 were used the diameter need not be much greater than the height of the face of the piece of work being milled.

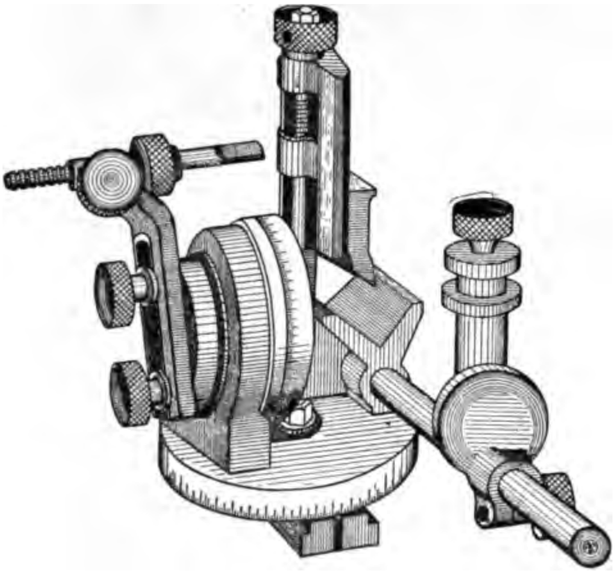

Fig. 216.

Generally speaking, cutters of this description are necessarily of a diameter that makes it advisable to use inserted teeth as shown in Fig. 218. The body may be made of cast iron, having a taper hole and key way, and held in place on the arbor by a screw.

The teeth may be made of tool steel and hardened, or of self-hardening steel if the cutter is to be subjected to rough usage. In either case they may be fitted to the slots by grinding on a surface grinder, and held in place by taper bushings and screws as explained under "Milling Cutters with Inserted Teeth." The construction of the body may be readily understood from the sectional view given in Fig. 219. The letters A, B, and C represent the diameter of cutter, width of face, and number of taper of the hole respectively, while D represents the key way.

The following table gives the dimensions of Face Milling Cutters of different diameters.

FACE MILLING CUTTERS.

A	B	C
5⅛"	2 "	No. 10 Brown & Sharpo Taper.
6⅛"	2 "	" 12 " " " "
7⅛"	2 "	" 12 " " " "
8⅛"	2⅜"	" 12 " " " "
9⅛"	2⅜"	" 12 " " " "

After boring and reaming the taper hole, the body of the cutter may be placed on a taper mandrel fitting the hole, and the ends and circumference finished to size. It should then be placed in the vise on the shaper or planer at the proper angle and the spline slot cut of an equal depth at each end of the taper hole. After removing the burrs it should be placed between the centers on the milling machine, and the slots cut for the teeth.

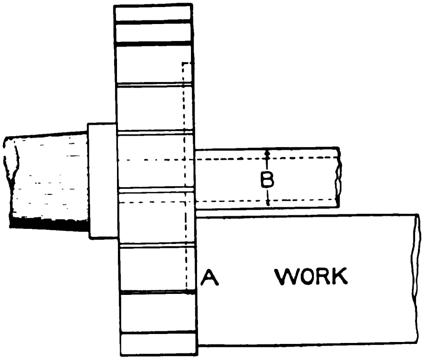

Fig. 217.

When the teeth are firmly secured in their proper places, they may be ground for clearance; the same general instructions given for grinding other forms of milling machine apply to this form.

Arbors For Face Milling Cutters. In. Fig. 220 is shown an arbor to be used in connection with *face* milling cutters. The shank A fits the hole in the spindle of the milling machine. B is the body which fits the taper hole in the cutter; this portion of the arbor has a spline which fits a spline slot in the cutter. A screw C enters the body of the arbor and is used in holding the cutter on the arbor. D is a nut used to force the cutter off the arbor when it is necessary.

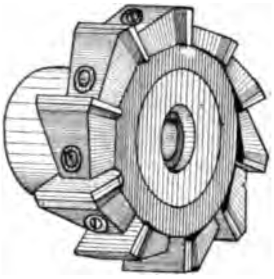

Fig. 218.

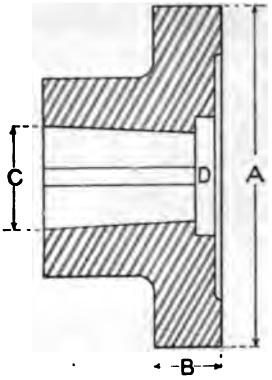

Fig. 219.

Stock used in making an arbor for a face milling cutter should be strong and stiff, and on this account tool steel is generally used. After squaring the end and roughing out the circumference, one end should be run in the steady rest and the screw hole in the end drilled and tapped, after which it should be countersunk at the end to furnish a center for use in turning and finishing. The tenon should now be turned to size and milled to thickness. If necessary to harden the end of the tenon it should be done before finish turning the arbor to prevent springing when heating. After turning the taper to fit the hole in the milling

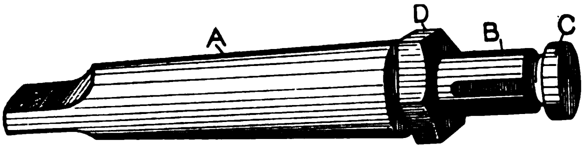

Fig. 220.

machine spindle, and on the opposite end to fit the cutter, the thread may be cut for the nut D, Fig. 220, after which the arbor may be cut for the spline as already explained.

The result will be more satisfactory if the two tapers are left a trifle large until after cutting the spline cut and are then ground to fit. Although the spline is intended to fit snugly in the slot in the arbor, the fit should not require pressure enough to endanger the truth of the arbor when it is pressed to position.

DRILL JIGS.

A drill jig is a device for holding work so that one or more holes may be accurately drilled; the locations of the holes may be governed by hardened bushings (guides) through which the drills run.

The design of a jig depends entirely on the shape of the piece and the nature of the work to be done. Jigs should be so designed that work may be placed in and taken out of them as quickly as possible. The fastening device should allow rapid manipulation, yet be capable of holding the work without danger of a change of location.

The construction of drill jigs calls for as great accuracy as any branch of the tool-maker's business; but no undue accuracy should be indulged in. If the location of a hole is near enough when within a limit of variation of $\frac{1}{16}$ inch it is a waste of time to attempt to get it within .0005 inch. Yet if the work is of such character that it is necessary that the holes be within a limit of variation of .0001 inch or even closer, every effort should be made to locate the drill bushings as accurately as possible.

While the design of the jig and the character of the work to be drilled must necessarily determine the method of construction, a few general points may not be amiss. The amount of *finish* given the exposed surfaces of a jig must be determined by the custom or requirements of the individual shop. In many shops it is not considered necessary nor advisable to finish the surfaces any more than to allow of their being wiped without the waste sticking to the jig.

A jig should be constructed so that it may be easily cleaned. Chips or dirt between the piece of work and the seating surface, or between the work and the stops, or locating points, throw the work out of true. As a result the holes will be at a wrong angle to the working surface, or they will be improperly located. Either condition would make the pieces unfit for use on most work, consequently bearing surfaces (wherever possible) should be cut away leaving several small seating surfaces, rather than one large one. A, Fig. 221, shows a piece of work resting on its entire seating surface; while B shows a surface cut away to leave six bearing points. If the seating surface is to be cut away as described, the raised portions should be so located that the article cannot be sprung by the action of the cutting tools or from any pressure that may be applied by any fastening device; otherwise the work will be thrown out of true as badly as though chips were lodged between the work and the seating.

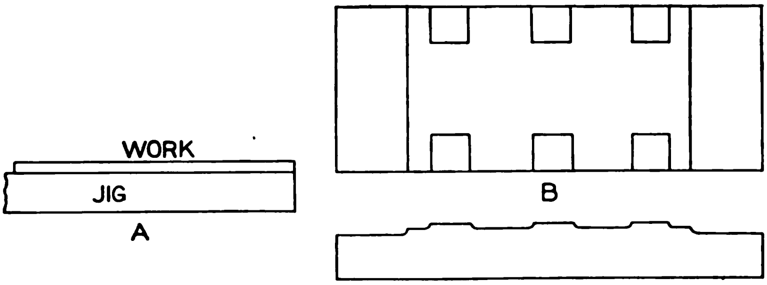

Fig. 221.

It is advisable, whenever possible, to divide a long, locating bearing into several short surfaces, thus decreasing the chance of holes becoming inaccurately located. When making jigs for pieces that are likely to have burrs at any given point, it is well to cut a depression in the seating or locating surfaces for the burr to set in, thus preventing the work being incorrectly located.

Seating surfaces should be made smooth so that chips and dirt may not stick to them, but they should not be polished nor finished as this would necessitate unnecessary cost and might cause the surface to get out of true.

A jig must be handled by the workman, and a clumsy jig cannot be handled as readily as one designed so that the workman can use it to advantage.

Sharp corners should be avoided wherever possible, and all handles or similar devices should fit the hand. If not, the amount of work done will not be the maximum, as the operator cannot do as much work with a jig which tires the hand and wrist.

As already stated the accuracy with which a jig should be constructed depends entirely on the nature of the work to be done, yet it should be borne in mind that any inaccuracy must of necessity be duplicated in the work.

EXAMPLES OF JIGS.

A few designs of jigs will now be considered to show the general requirements and the methods of construction.

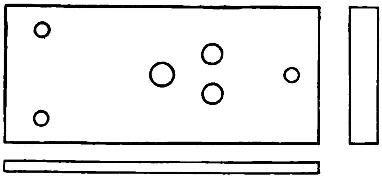

Fig. 222.

The slab jig, shown in Fig. 222, is the simplest form in use; it consists of a piece of flat stock of suitable thickness and of the same general outline of the piece of work to be drilled. The work may be clamped to the jig by means of U clamps, or parallel jaw clamps. If the jig is made of machinery steel the walls of the holes may be case-hardened by heating the jig red hot and sprinkling powdered cyanide of potassium around the hole, reheating in the fire and plunging in water; it should be worked back and forth in the bath so that the water will circulate through the holes. While this form of jig answers very well where but a few pieces are to be drilled, it is not suitable for permanent equipment on account of the wear of the holes. To overcome this, the holes may be made sufficiently large to receive hardened bushings having holes the size of the drill to be used. Fig. 223 shows this construction.

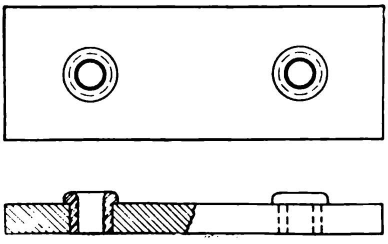

Fig. 223.

When holes are to be drilled at certain distances from one or more edges, it is necessary to have stops against which the work may rest. These stops may be pins, a shoulder, or a rib.

If the outline of the work has been finished by any process — as milling, punching or profiling — that insures uniform lengths and widths, the locating points may be placed on all sides of the piece as shown Fig. 224, in which pins are used as stops or locating points. It is necessary to flatten the pins on the sides that come in contact with the work to prevent wear.

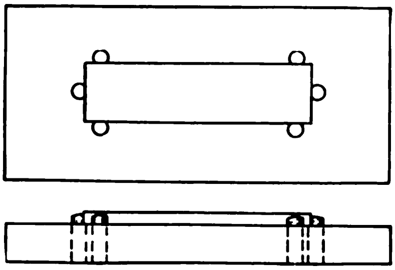

Fig. 224.

When a jig is to be used constantly, it is advisable to have a shoulder or rib for the work to rest against, rather than pins, as the former will not wear as rapidly. Fig. 225 shows the same form of jig as Fig. 224 except that ribs are substituted for pins.

When there is no surety that the dimensions of the different pieces are exactly alike it is advisable to locate the pieces in the jig from certain portions. The work must be forced against the locating points by means of a screw, cam or wedge. With a screw the work may be forced to position and held there even when the dimensions of the piece vary considerably. The cam is operated much more quickly than the screw and holds the work firmly when the size of the pieces vary but little. For certain purposes the wedge is an admirable holding device, but it is not generally used. Fig. 226 shows a jig in which the work is located from one side and end; the work being forced against the stops by means of a screw.

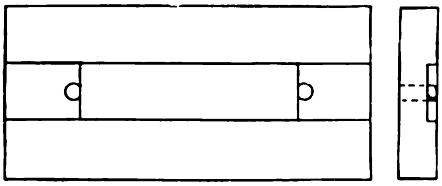

Fig. 225.

Fig. 227 represents the same jig having a cam instead of a screw.

When making any of these styles of jigs, the holes to contain the bushing may be located by several methods. If extremely accurate work is not necessary, a templet may be made, or a model

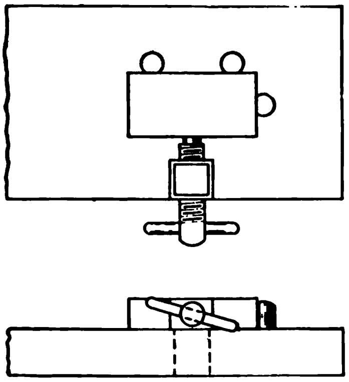

Fig. 226.

piece used having the holes properly located; this piece may be placed in the jig and by means of drills the holes are transferred to the jig. If the bushings are to be used the holes may be enlarged by a counterbore having a pilot which fits the drilled hole and a body of the desired size of the bushing. While this method is cheap and good enough for certain classes of work, it is not advisable to use it for a very accurate job.

Another inexpensive method which insures *fair* results is to drill the holes as described above, then run a drill or reamer a trifle larger than the holes in the templet through the holes in the jig. Now place the templet in position and by means of a counterbore having a pilot which fits the hole in the templet counterbore the jig to the templet as shown in Fig. 228. Better results will be obtained if the ends of the teeth of the counterbore are made of the shape shown in Fig. 229, especially if the drilled hole should have run from its proper location.

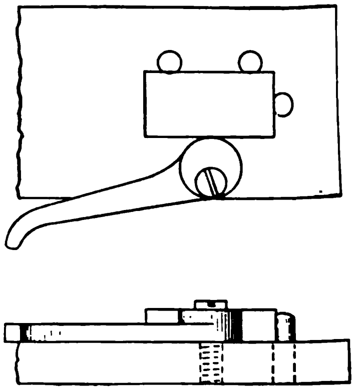

Fig. 227.

A third method is used when the bushing holes must be located by measurement, or when there is no templet or model piece. By means of a surface gauge having the point of the needle set at the proper height from a scale attached to an angle iron, as shown in Fig. 230, scratch a dimension line on the surface which has been colored with blue vitriol. The needle is first set to the height of the locating rib. The scale attached to the angle

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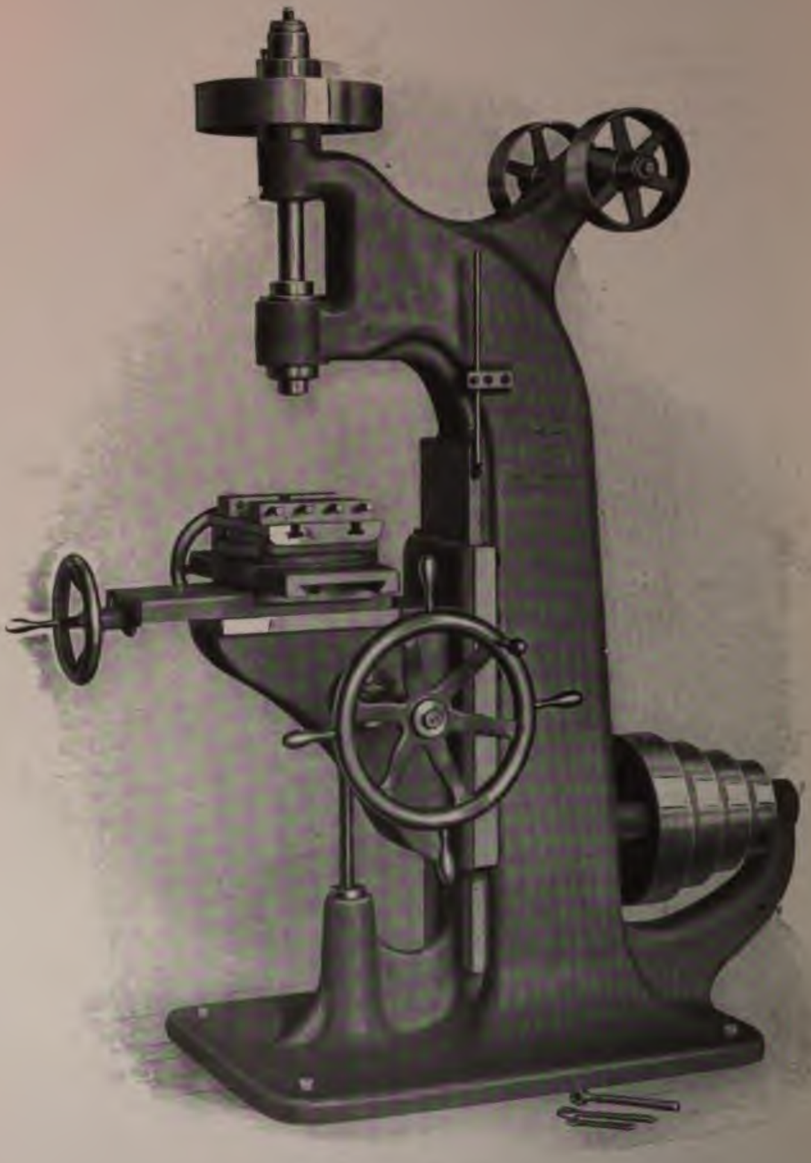

DIE SINKING MACHINE.
Pratt and Whitney Co.

iron is adjusted so that the needle is at the exact height of one of the inch lines if possible, if not, at one of the half of quarter inch lines. The needle may then be raised to locate the center of the first hole and a line scratched while the jig is on edge. The centers of the other holes may now be laid off on this plane, after which the jig may be turned one quarter way around to locate the hole from the other measurements. Where the lines intersect prick punch the surface of the jig. For this work *do not* use the center punch made for centering work to be turned in the lathe. Use the prick punch which should be much lighter than the ordinary center punch; Fig. 231 shows the two punches. The point of the prick punch should be ground in some form of grinder in which it may be held and revolved in order that the point may be perfectly round. If this is not done it will be impossible to get the point of the center indicator to run true when attempting to true the jig on the face plate of the lathe.

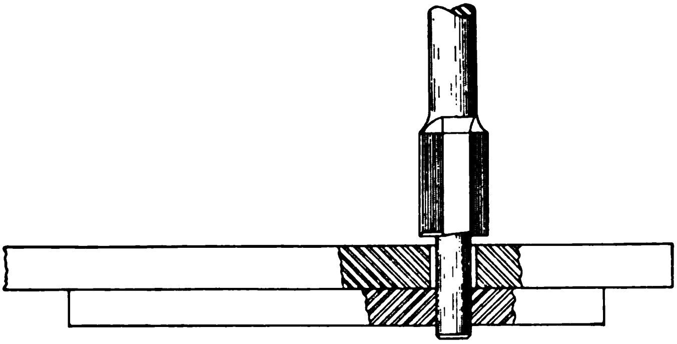

Fig. 228.

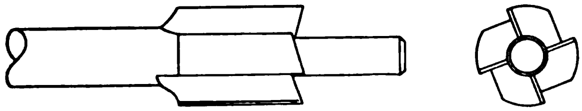

Fig. 229.

While the above method might be properly classed as an approximate measurement, an experienced workman can locate the bushings within a small limit of variation. More accurate work will result if the height gauge is used in laying off the dimension lines. The bottom surface of the extension is set to the height of the locating rib, as shown in Fig. 232; then by means of the vernier it may be raised to the exact height of the dimension desired, and the line scribed by means of the point of the extension.

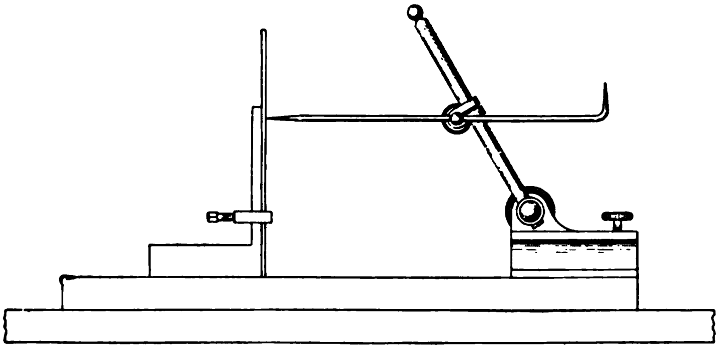
Fig. 230.

While this method insures greater accuracy in laying off dimension lines and is sufficiently accurate for most work, it is open to the objection that the tool maker may change the location of centers somewhat when prick punching.

When *precise* measurements are desired many tool makers determine the location of bushing holes by means of hardened discs or buttons. A very common size, Fig. 233, if $\frac{1}{2}$ inch diameter, $\frac{3}{16}$ inch thick and having $\frac{1}{4}$ inch hole. While it is not essential that the diameter be any particular size, it must be some fraction divisible by two without a remainder, as one half the size of the disc is considered in all computations. If the disc is .500

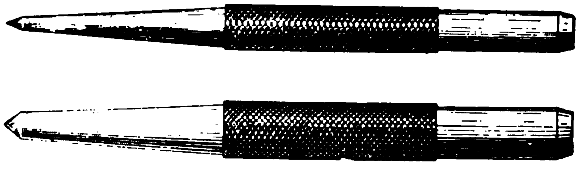
Fig. 231.

inch diameter, .250 inch is the decimal to be considered; but if the disc were $\frac{9}{16}$ (.5625) inch diameter it would be necessary to consider the decimal .28125 in all computations. In locating the disc most of the measurements are made with the vernier caliper, and as the tool is not graduated to read closer than .001 inch it would be impossible to consider the fractions of a thousandth of an inch; consequently discs .500 inch diameter are generally used.

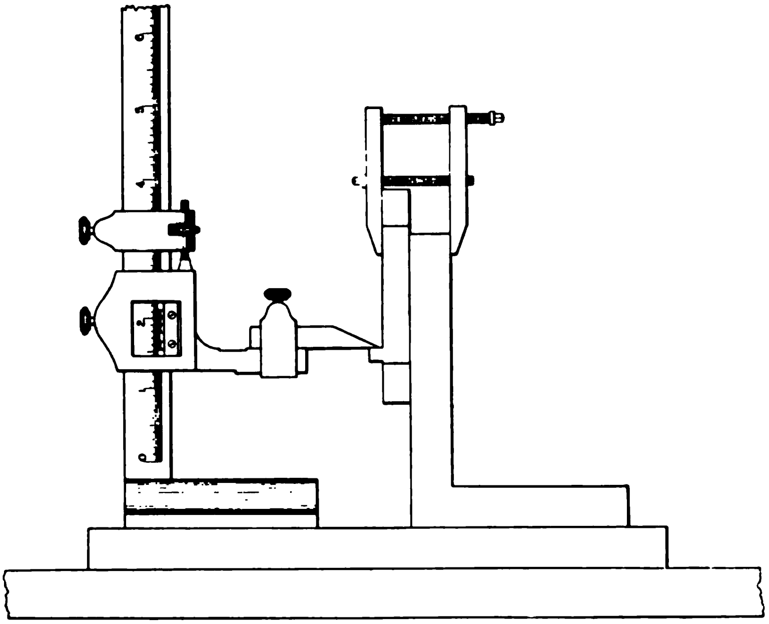

Fig. 232.

The locations of the different holes are laid off by means of the surface gauge, setting the needle to the scale fastened to an angle iron as already described. The holes are drilled and tapped for a screw somewhat smaller than the hole in the discs. The discs are now attached to the jig by means of screws. As the screws do not fill the holes in the discs, they may be moved until properly located. Fig. 234 shows a jig having the discs located in relation to the stops.

After properly locating a disc at each point where a bushing is desired, the jig may be fastened to the face plate of the lathe.

The jig must be so located on the face plate that one of the discs will run *perfectly* true. This may be determined by a test indicator operating on the outside of a button, as shown in Fig. 235. After locating so that the disc runs exactly true, the disc may be removed and the hole bored to the required size. The jig may now be moved to bring another disc to the proper location, after which it may be removed and the hole bored; this operation may be repeated until all the bushing holes are bored.

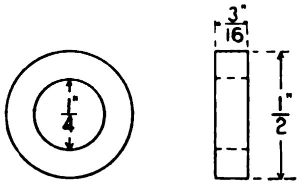

Fig. 233.

When jigs are made for permanent equipment, or if they are to be used constantly, it is well to provide some means of raising them from the drill press table to avoid inaccurate work occasioned by chips. When the jig is made of cast iron, the legs are sometimes cast solid with the jig as shown in Fig. 236. In order to grasp a jig handle in a manner that will not be tiresome to the wrist or hand, and allow sufficient room between the handle and the table of the drill press so that the fingers may not be cut by chips, the legs are made of a length that will raise the handle about 1⅛ inches above the table. As cast-iron legs of this length would be too weak, it is customary to make the legs of tool steel hardening the ends that come in contact with the drill press table.

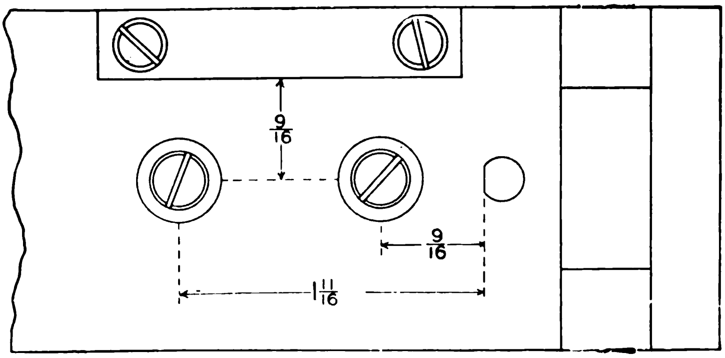

Fig. 234.

While the form of jig shown in Fig. 222 would give satisfaction on certain classes of work, the process of putting the work in, and taking it out of the jig would be very slow, as it would be necessary to clamp the work securely to resist the pressure of the cutting tools.

In order that work may be handled rapidly during these operations, jigs are designed so that the work will rest on the base of the jig as shown in Fig. 237. A leaf or cover containing the bushings can be raised when putting the work in place and taking it out.

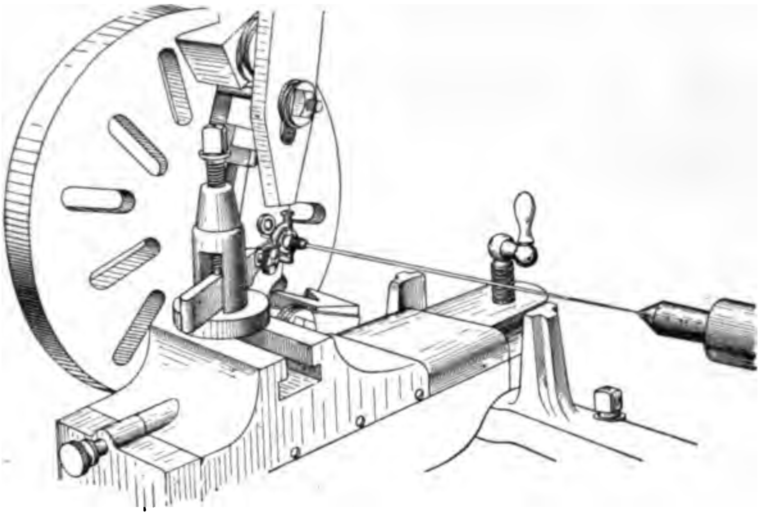

Fig. 235.

When the pieces to be drilled are of a uniform thickness the leaf may be made to rest on the piece. But should the pieces vary in thickness the leaf would not be parallel to the base; consequently the hole in the bushing would not be at right angles to the piece to be drilled. For this reason a little space is left between the top of the piece to be drilled and the bottom of the

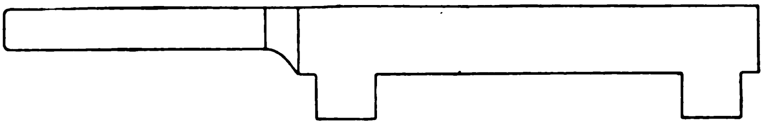

Fig. 236.

leaf, as shown in Fig. 238; a steady pin having a shoulder is located at the handle end of the jig. The upper end of pin may project into a hole in the leaf as shown thus relieving any strain on the joint of the jig occasioned by the action of the cutting tools.

When holes are to be drilled from opposite sides of a piece

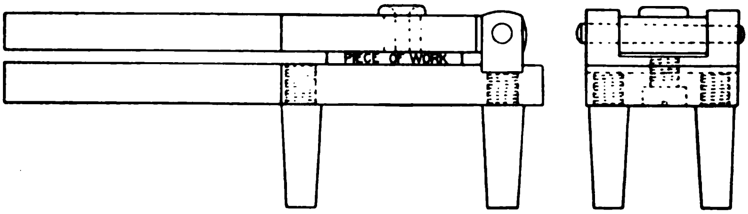

Fig. 237.

of work, as shown in Fig. 239, a jig may be constructed having legs on both upper and lower sides, but both sets of legs should be solid with the base as shown in Fig. 240.

If the two end holes in Fig. 239 are of the same size and it is necessary to use a drill press having but two spindles, the legs on each side should be of a length that would make it possible to

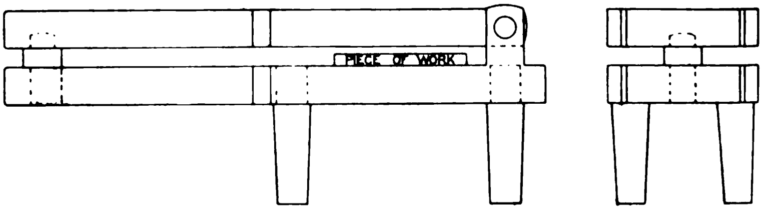

Fig. 328.

set the stops so that the drill would cut the required depth on each side. If a drill press having three or more spindles is to be used, the jig legs may be of a convenient length, as two drills of the same diameter can be used in two different spindles, each one to drill the required depth when the stop is set.

Drill jig legs are generally made of tool steel and are screwed into the base of the jig: the thread on the legs should be a good fit in the base. After screwing in place the ends of the legs should be machined to length by milling or planing; the legs may then be removed and the ends that come in contact with the drill press table hardened. The legs may now be polished (if that is allowable) and then screwed in place. The ends should now be ground to such a length that the surface where the work is seated will be of the correct height above the drill press table.

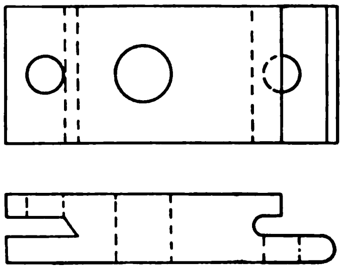
Fig. 239.

Grinding the ends of the legs can best be done in a surface grinder, or some form of universal grinder designed for surface grinding. After grinding, the ends of the legs may be lapped to remove any irregularity that may result from grinding. A very good lap may be made from a flat plate or block of cast iron. The surface to be used may be planed flat and smooth, then a series of grooves cut to form squares, as shown in Fig. 241. These grooves may be cut with a V-shaped tool and should be $\frac{1}{4}$ inch to $\frac{1}{64}$ inch

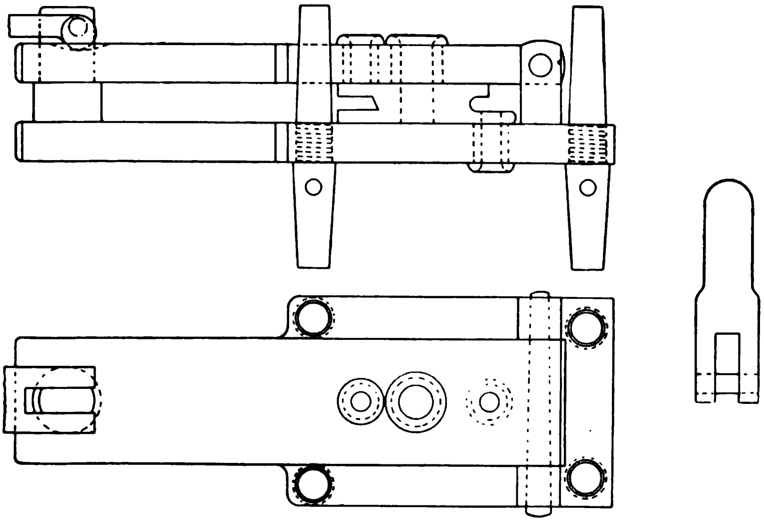
Fig. 240.

to $\frac{1}{32}$ inch deep. The grooves catch the emery and feed it to the work being lapped. If the pressure is not equal one leg may be

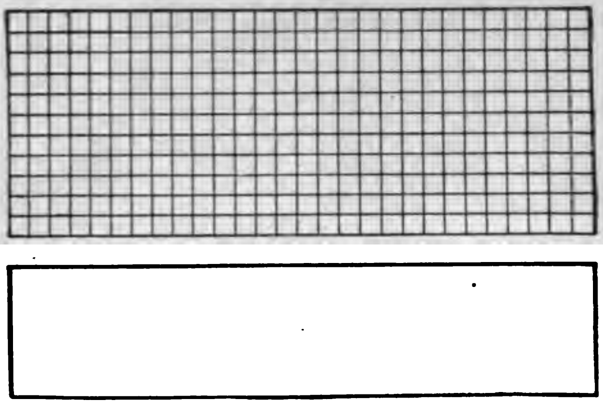

Fig. 241.

cut shorter than the other, or may be lapped out of true, causing the jig to rock.

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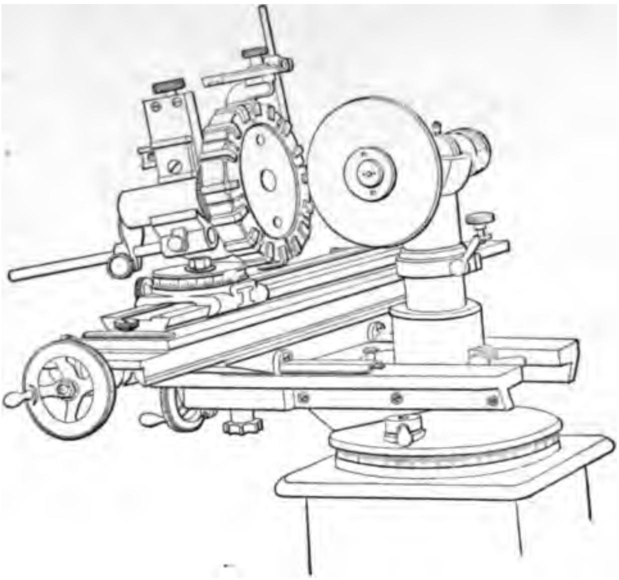
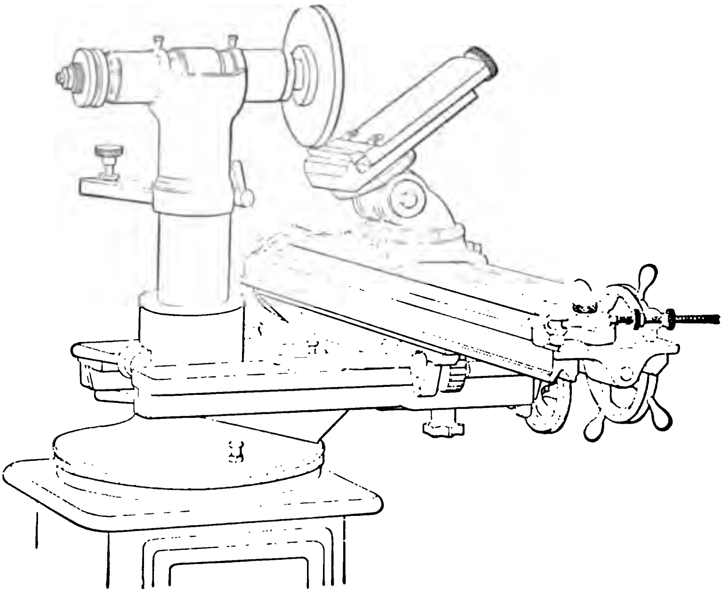


GRINDING A LARGE FACE CUTTER.



UNIVERSAL VISE ARRANGED FOR GRINDING BEVELLED SURFACES.

Norton Emery Wheel Company.

TOOL MAKING.

PART III.

DRILL JIGS.

Fastening Devices. Various devices are used to fasten the leaf of a jig to hold the work in place or to clamp the leaf in position. The forms used depend upon the class of work being operated on.

If the leaf must be fastened solidly and the amount of time consumed is not of great importance, some form of screw clamp may be used. If, however, the work must be handled rapidly, the clamping device is generally operated by some form of a cam. However, a screw clamp may be designed to work quite rapidly.

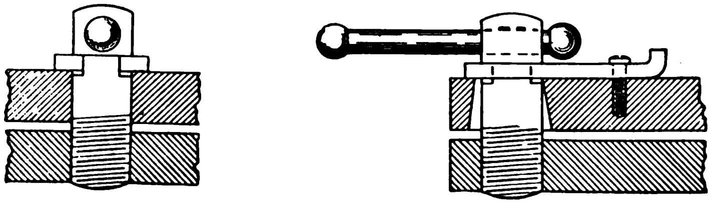


Fig. 242.

Fig. 242 shows a screw clamp which consists of a screw which has a hole drilled through it to receive a pin which is used as a lever to operate the screw. The screw is necked $\frac{1}{16}$ inch deep, the necking being $\frac{1}{8}$ inch wide; a flat washer is attached to the leaf of the jig by a small screw as shown. A slot of the width of the screw is cut in this washer in order to allow it to slide back and forth. In the end of the washer is a slot the width of the bottom of the necking in the screw. The other end of the washer is turned up as shown, in order to furnish a means of pushing back and forth. When the jig leaf is closed, the washer is pushed forward and the ends engage in the slot in the screw. One turn of the screw binds it very tightly. When the screw is given one turn to loosen it, the washer may be pushed back and the jig leaf raised.

If a quicker form of clamping is desired a cam may be used. The form represented in Fig. 240 is rapid and powerful.

Were it not necessary to use much power, but extreme rapidity of action is desired, a hinged cam lever of the design shown in Fig. 243 may be used. The cam lever is pivoted to the base of jig by means of a pin as shown. The lever passes into a slot in the leaf and the bearing surfaces on the under part of the head come in contact with the inclined surfaces at the end of the leaf.

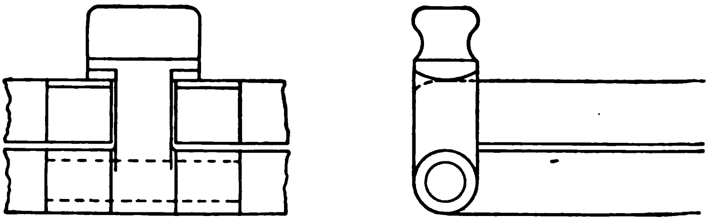


Fig. 243.

Bushings. Bushings of hardened tool steel are made for a permanent means of guiding the cutting tools. The hole in the bushing is made to fit the cutting tool that is to be guided. There are various forms of bushings; the plain straight form shown in Fig. 244 is sometimes used, but is objectionable because it may be pushed into the jig if the cutting tool is too large to pass through the hole.

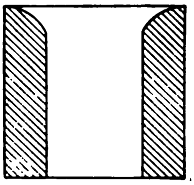


Fig. 244.

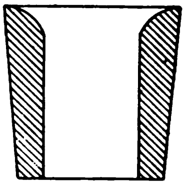


Fig. 245.

To overcome this tendency they are sometimes made **tapering** on the outside as shown in Fig. 245, but as this is an expensive form

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to make, and as it is an extremely difficult operation to bore the bushing hole in the jig, this form is not generally used for permanent bushings.

The most common form of bushing is straight with an enlarged portion or head. When no allowance is made for grinding on the outside it is commonly made of the form shown in Fig. 246. If the shoulder under the head is square, it is likely to crack at the sharp corner, or the head may be broken off when being forced in position. In order to avoid these difficulties a fillet is left under the head as shown in Fig. 247.

When it is essential that the location of the drilled hole or portion of the piece being machined in the jig be exact as to location, the tool must fit well in the bushing; and as the size and shape of the bushing is likely to change when hardening, it is advisable to leave enough stock to grind to size both inside and out. It is essential that the outside of the bushing be exactly concentric with the inside. After grinding and lapping the hole to size, the bushing may be placed on a mandrel which runs true and the outside ground to size. When machining a bushing which is to be ground on the outside it is necessary to neck in, under the head, as shown in Fig. 248, in order that the emery wheel may pass entirely over the part being ground and insure a straight surface. The under side of the head which rests on the upper surface of the jig should be ground in order that it may be true with the surface of the jig.

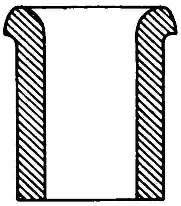


Fig. 246.

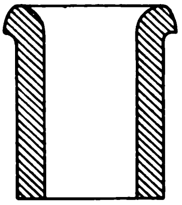


Fig. 247.

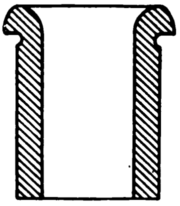


Fig. 248.

When grinding a bushing, a mandrel should be used which has been tested for truth. The mandrel should be straight or of very slight taper. If the taper is considerable, one end of the hole in the bushing, will not fit and the outside of the bushing will not be concentric with the hole. Consequently no matter how careful the tool maker might be in laying out his work and in boring the holes for the bushings the jig will not be accurate.

Size of Bushings. The outside diameter of a bushing is often determined by the design of the jig; for instance, two holes are often located so near each other that it is impossible to make the bushings much larger than the holes through them. Wherever possible the outside diameter should be made enough larger than the hole to leave a reasonably thick wall. A bushing with thin walls is likely to close in when being pressed to its seating; then again, if a cutting tool binds in a bushing with thin walls, the bushing becomes loose and turns in the jig.

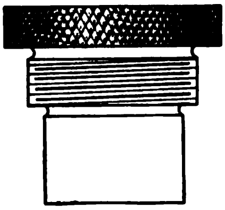


Fig. 249.

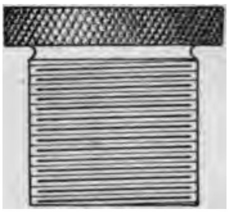


Fig. 250.

Removable Bushings. It is sometimes advisable to do two or more operations in the same jig. After drilling a hole it may be considered good practice to counterbore or tap it, or possibly it may be better to do the three operations while the work is seated in the jig. In such cases the bushing having a hole the size of the drill must be removed and one with a hole fitting the tool to be used inserted.

A very simple way of making a removable bushing consists in boring the hole in the jig large enough to receive a hardened bushing with a hole the size of the outside of the bushing to be used. If the hole in the large stationary bushing and the outside surface of the removable bushing are lapped smooth after grinding, they may be used for a long period before wearing enough to appreciably affect the location.

Tapered removable bushings are sometimes used; but on account of the expense of producing them and the fact that chips and dirt readily throw them out of their true locations, they are not very common.

Fig. 249 shows a form of removable bushing threaded on the outside to fit a threaded hole in the jig. If the thread on the outside of the bushing runs the entire length the process of screwing it in and out of the jig is necessarily very slow; consequently it is advisable to have but few threads. The balance of the length may be made to fit a bearing in the jig. If it is advisable to thread the entire length as shown in Fig. 250, the hole should be ground true with the thread to prevent change of shape in hardening. As it is not well to attempt to grind between the lands of the thread with the facilities in the ordinary machine shop, it is necessary to grind the hole true with the thread. This can be done satisfactorily by placing a piece of stock in a chuck on a lathe having a grinding attachment.

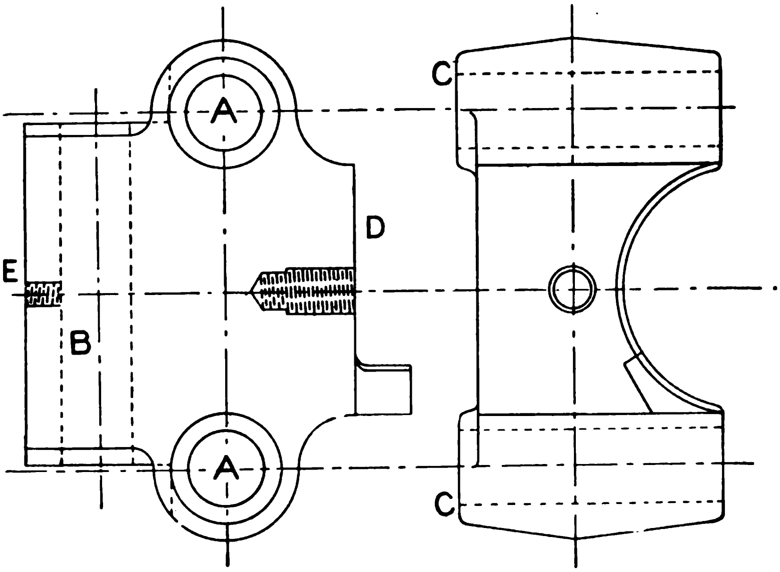


Fig. 251.

After drilling and boring the hole to tapping size, the thread may be chased so that the bushing is a good fit in the hole. It may then be screwed in and the hole ground to size.

If the piece of work is of a shape that makes it necessary to operate on all sides and the outline prevents the use of a clamp jig of the forms shown, a box jig must be used.

A Box Jig is made in the form of a box; the work is located in the jig by means of stops or locating points which differ according to the nature of the work. It is often advisable to design this form of jig so that all the holes in the work may be drilled at one setting; that is, if there are twenty holes in the piece, the jig is designed to allow drilling all the holes while the piece is in the jig. For other work it is advisable to make two or more jigs to

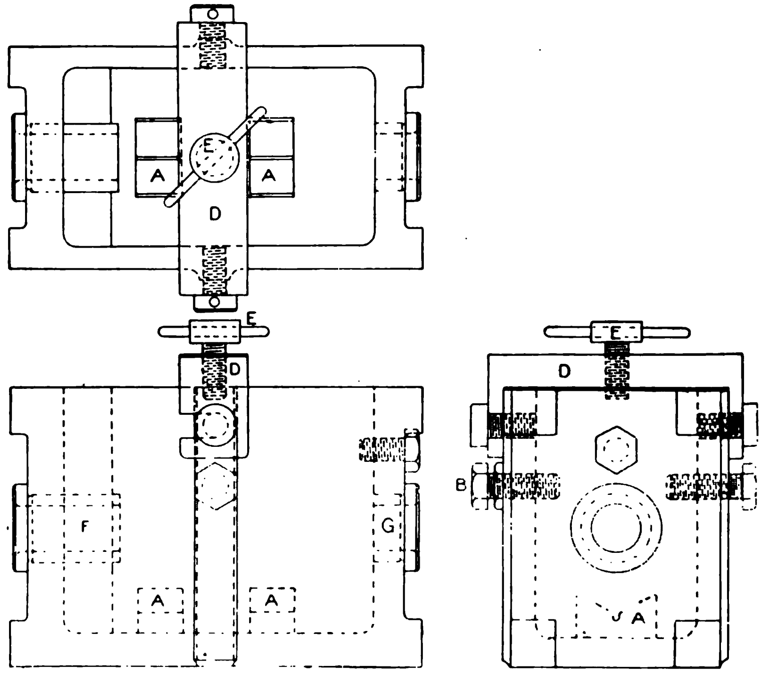
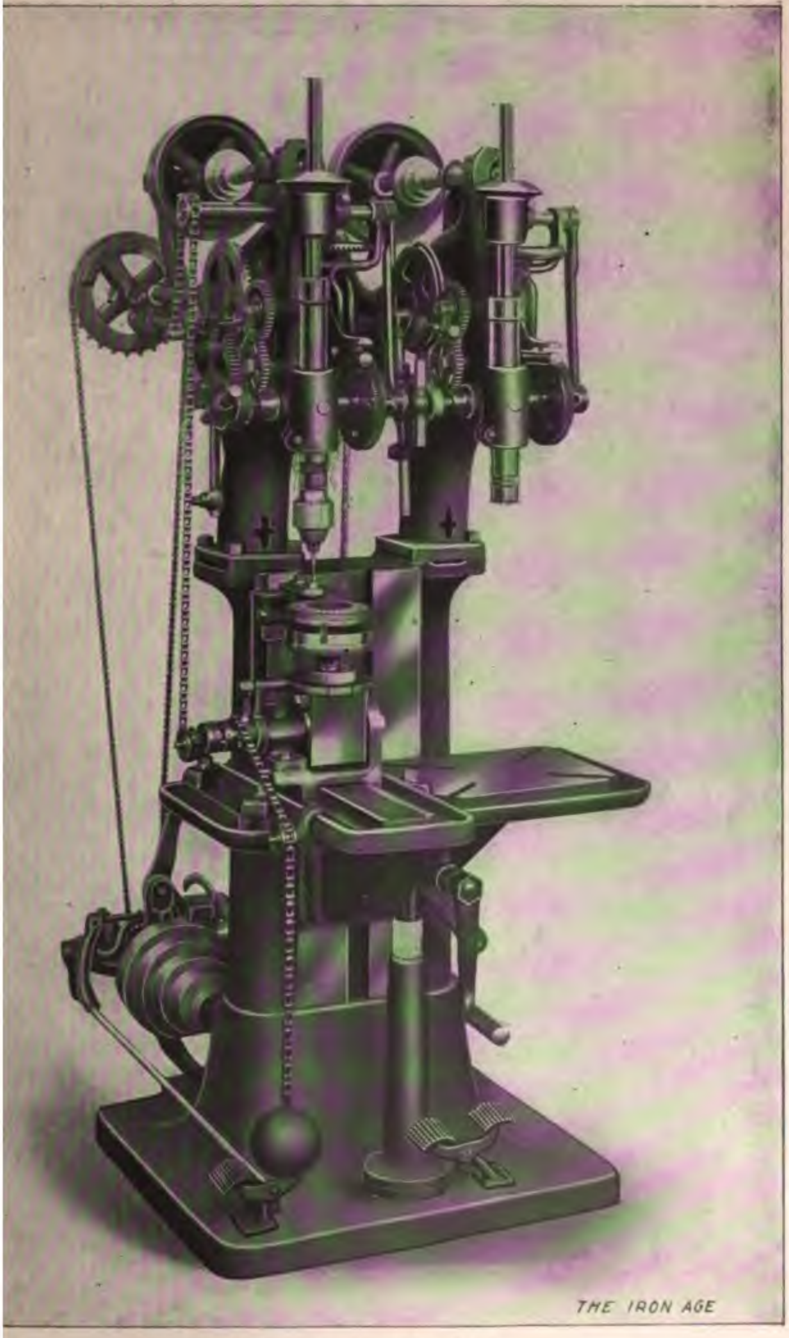


Fig. 252

drill the holes; this is the case when some part of the piece is to be machined after one or more holes are drilled but before drilling the others.

In Fig. 251 a piece of work is shown (three eighths size); through the piece it was necessary to drill three 1-inch holes as shown at A, A and B. As it was necessary to have the holes A A an *exact* distance from B it was found by experience that much better results could be obtained if the hole marked B was



TWO-SPINDLE AUTOMATIC DRILL
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drilled and reamed in a jig, the piece taken out of the jig and the portions marked C and C milled in exact relation to the hole B and as nearly at right angles with the side of casting marked D as possible. After milling the portions C C, as described, the piece was placed in another jig locating it by the hole B and the surfaces C C; the holes A A were then drilled and reamed. In order to drill the hole B the jig shown in Fig. 252 was used.

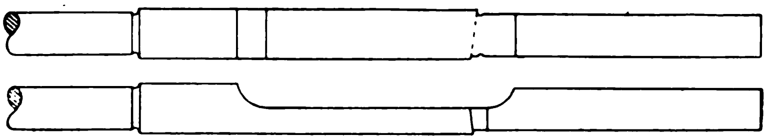


Fig. 253.

The piece was placed in the jig with the rounded surface E resting in two V blocks as shown at A. It was located by means of the fixed stop screw B and forced against A by the screw; it was held in position by the screw E which was located in the strap D. This strap was removed when putting a piece of work in the jig, or taking it out. As it was necessary to have the hole straight and true with the locating points, it was reamed with a single lip

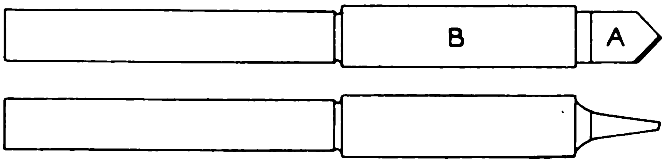


Fig. 254.

reamer having a pilot as shown in Fig. 253. The hole was drilled somewhat smaller than finish size ($\frac{1}{64}$ inch); the reamer was entered in the hole, the pilot fitting the bushing G. While the body of the reamer fits the bushing F, as previously explained, the single lip reamer acts on the same principles as a boring tool used in the engine lathe; the result being a hole straight and true. As it is necessary to have the hole in the upper bushing of the size of the body of the reamer, and as a drill $\frac{1}{64}$ inch smaller than this size must be used in drilling the hole, it was advisable, in order to properly start the drill, to use a transfer drill shown in Fig. 254, the cutting portion A of drill being the size of the drill to be used in drilling the hole, while B fits the hole in the bushing. By means of this drill a hole the size of the drill to be used was started in the casting perfectly true with the hole in the bushing yet somewhat smaller. When the hole had been drilled to a depth of $\frac{3}{16}$ or $\frac{1}{4}$ inch, the transfer drill was removed and a twist drill of the proper size used to finish the drilling. When the piece of work was taken from the jig the portions marked C C, Fig. 251, were milled as explained. The piece was then placed in another jig, a pin which fits the reamed hole passed through the locating bushings and through the hole; by this means it was located to properly drill the other two holes. The second jig so closely resembles the first it is unnecessary to illustrate it.

PUNCH AND DIE WORK.

THE DIE.

A die used for punching a blank from a sheet of metal is termed a blanking die, and is generally considered as belonging to one of three classes: plain (or simple) die, gang die or compound die.

A set of blanking dies consists of a male die or *punch* and a female die or *die block*. The die block is that part of the die which has a hole of the same outline as the desired blank; the male die, or punch, is of a shape that fits the impression, or hole, of the die block.

When punching work on a punching press, the stock is placed on the die and the punch forced through it into the die; this drives a piece of stock of the same outline as the hole down into the die block. Now as the punch is forced through, the metal in the sheet closes on the punch and is raised by it. In order to prevent this the die block is provided with a *stripper plate* (or stripper). The stripper is fastened to the die or to a shoe holding the die at a height that allows the metal to be punched to pass freely between it and the die. The stripper must be strong enough to force the stock from the punch without springing, especially if the punch is slender and the stock thick, because under these conditions the punch would be sprung or broken.

In order to guide the stock over the die and leave the proper amount of margin or scrap at the edge of the sheet, a *guide* is furnished. The guide is usually made of stock sufficiently thick to bring the stripper the proper height above the face of the die.

A *gauge pin* (or stop) is usually provided; this pin is located so that the proper amount of scrap is left.

In Fig. 255, A is the die block, B the hole through the die block of the shape of the piece to be punched, C the stripper, D the guide and E the gauge pin or stop.

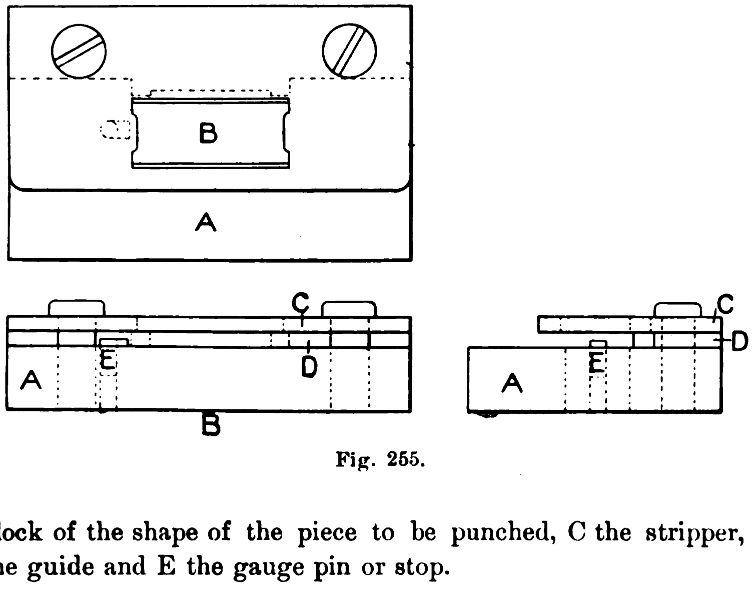


Fig. 255.

Dies are held in position on the punching press bed by various methods, the most common of which is by means of the forms of hold-fast shown in Figs. 256 and 257. These die holders are known by various names, such as chair, bolster, chuck and die holder. Large dies are clamped to the bed of the press.

Dies are usually beveled on the edges that come in contact with the die holder to prevent their rising from the seat. The angle given to the edges varies according to the ideas of the designer. An angle of 10° from the vertical gives satisfaction, although some mechanics insist on an angle of 15° or even 20°.

Fig. 258 shows a die, whose edges are at an angle of 10°, in a die holder; the die being held in place by set screws. It is generally considered advisable to place a gib between the set screws and die as shown. Sometimes the gib is omitted, the set screws bearing directly on the edge of the die. Some tool makers prefer a die holder without set screws, the die being held in place by the gib which is made wedge-shaped and is driven to place, thus securely holding the die.

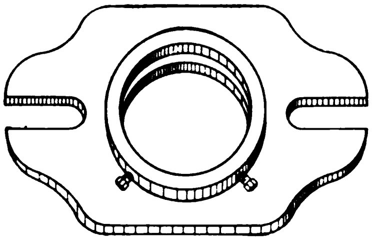


Fig. 256.

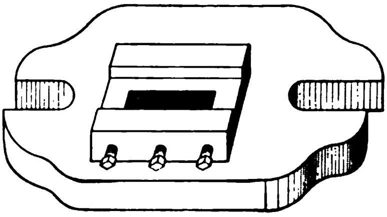


Fig. 257.

Fig. 259 shows a method of holding dies which allows the die to be easily set in position when rigging up. The die may be placed on the seating of the die holder and brought to the proper location; the set screws may then be brought against the edge of the die, or against strips of steel which may be placed between the edges of the die and the set screws.

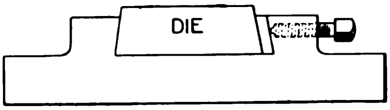


Fig. 258.

When making several dies of equal width and thickness a good method is to plane the two sides of a bar to remove the outer surface, then bevel the edges to the required angle. Pieces may then be cut off to any required length as wanted.

The upper surface of the die may be finished smooth by planing with a smoothing tool; it may be ground in a surface grinder, or it may be finished with a file. It is necessary to have the surface smooth in order to lay out the correct shape of hole, as it cannot be laid out correctly or distinctly on a roughly machined surface.

The face, or upper surface of the die is now covered with blue vitriol solution and the outline of the piece to be punched laid out. A die should be laid out in such a manner that the stock to be punched may be readily fed to the die. The *grain* of the stock should run in the proper direction if the product is to be a tempered spring or any article where the grain of the stock must be considered.

After the die has been carefully laid out from a templet, or drawing, all round corners should be drilled with a drill of the proper size, and reamed from the back side of the die with a taper reamer to give the desired clearance; the balance of the stock is removed by drilling, as shown in Fig. 260. The method of removing the center, or core, depends on the custom practiced by the individual die maker; one may drill the holes so that they break into one another. When this method is adopted it is advisable to use a straightway (straight fluted) drill. Another will drill small holes and use a counterbore to enlarge to size; the counterbored holes breaking into each other.

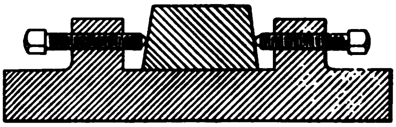


Fig. 259.

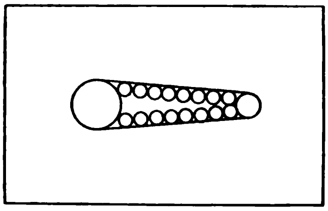


Fig. 260.

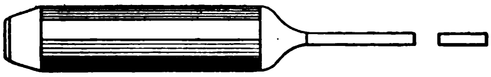


Fig. 261.

Usually the holes are drilled with at least $\frac{1}{64}$ inch to $\frac{1}{32}$ inch between them, and then the intervening stock is cut out with a flat-ended "hand broach." Fig. 261 shows a tool of this description.

Generally speaking, the last mentioned method is the safest and quickest. After removing the center, the die may be placed in a die milling machine or a die sinking machine, and by using a milling cutter of the proper taper, the desired angle of clearance may be given; the amount of clearance varies with the nature of the work to be done.

When a die is milled on a die milling machine of the form shown in Fig. 262, the cutter spindle is underneath the die, the face of which is uppermost, consequently the milling cutter can be made largest at the shank end of cutting part, the required taper being given as shown in Fig. 263. If the outline of the hole is milled on a die sinking machine, it is necessary to use a cutter of the shape shown in Fig. 264 in order that the face of the die having the lines will be uppermost. After working the impression as near to shape as possible by milling, it can be finished by filing. In order to give the die the proper clearance the walls may be gauged with a bevel gauge of the form shown in Fig. 8. As the amount of clearance differs in various shops, and on different classes of work, no stated amount can be given for all cases; the amount varies from ¼° to 3°. The latter is excessive and is seldom given unless it is necessary that the piece punched drop from the die each time.

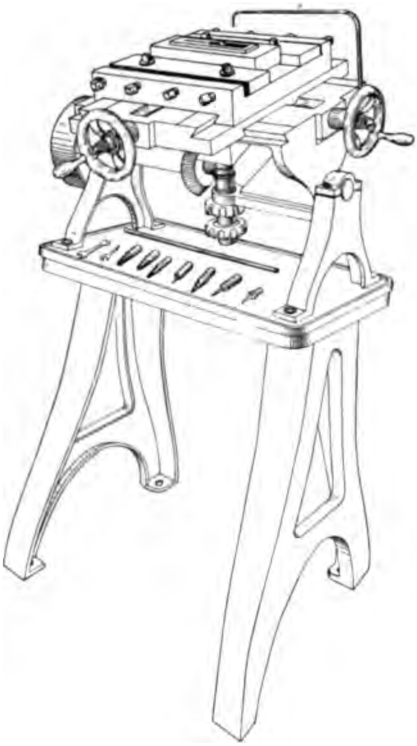


Fig. 262.

If the die is milled as described above it will be necessary to work all corners to shape with a file. If a universal milling machine having a slotting attachment is used, the corners can be properly shaped and the necessary clearance given by using suitably shpaed cutting tools, and turning the fixture to the proper angle.

Fig. 265 shows a slotting fixture attached to a universal milling machine, while Fig. 266 shows a fixture known as a die shaper which is also attached to a milling machine.

Die blocks have their cutting edges beveled in order that the blank may be cut from the stock by a shearing cut. *Shear* is given the face of the die to reduce the power necessary to cut the blank from the stock ; thus enabling a press to punch a blank from thicker stock. It also reduces the strain on the punch and die.

The face of the *die* is sheared when the blank, or piece forced through, is the product to be saved. But if the piece surrounding the blank is to be saved, and the blank is of no use, the face of the die is left perfectly flat and the end of the *punch* is sheared.

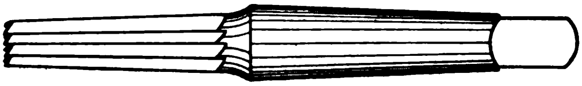


Fig. 263.

The cutting face of the die may be sheared by milling or planing to the desired angle which depends on the thickness of the stock to be punched and also the power of the press. A common method of shearing a die is shown in Fig. 267, which shows a section of a die used for punching a heavy spring. The end of the *punch* is left flat. The punching commencing at the center A, is continued with a gradual shearing cut as the punch descends until it reaches the ends BB, of the opening. The blank punched will be straight while the stock will bend somewhat unless it is quite stiff, in which case it springs back to shape when the pressure is removed.

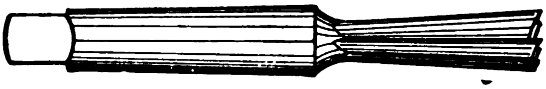


Fig. 264.

When the punching requires an amount of power in excess of the capacity of the press, as in the case of the forging shown in Fig. 268, it is necessary to trim the flash occasioned by the process of drop forging, and at the same time punch the end to shape as shown in Fig. 269. It is obvious that the material removed is of no value as a product, and as it is necessary to use a light press, the die may be given a shear as shown in Fig. 270; thus making it possible to do the punching on a press whose capacity is not equal to the job if the die had been sheared as shown in Fig. 267.

In order to facilitate the operation of grinding the face of a die, it is frequently made with a raised boss around the hole as shown in Fig. 271.

Sectional Dies. In order to make it easier to work dies to shape, they are sometimes made in two or more pieces; these are fastened together when in use. In the case of a plain die of the form shown in Fig. 272, the die is made in two pieces which are held in their relative positions by the dowel pin at each end as shown at A and B. When in the die holder they are held together in such a manner that they cannot spread. Dies of this form should have the surfaces that go together finished true; the pieces should then be clamped together and the dowel-pin holes drilled and reamed. They should then be taken apart and any burrs caused by drilling and reaming removed. The pins should now be inserted and the top and bottom of the die planed. The outlines of the piece to be punched may now be laid out and the round hole at one end drilled; after which it should be reamed from the back with a taper reamer to give clearance. The die may now be taken apart, and the opening cut out on the planer or shaper; the sections of the die being held at the proper angle to give the desired amount of clearance. After placing the two pieces together the opening may be finished with a file and scraper to the templet.

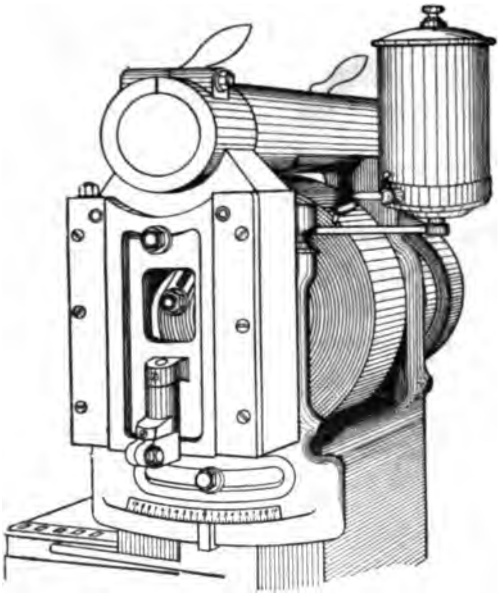


Fig. 265.

To hold the die together securely it is necessary to use a die holder of the form shown in Fig. 273. The die is represented in place in the holder which is held in the bolster which is in turn attached to the bed of the press. When the die is finished to the templet and the proper clearance given, make sure that the walls of the opening are straight (not crowning), although it is not always considered advisable to carry the clearance to the edge, as the size of the opening would then increase every time the die was sharpened. In such cases the clearance extends from the bottom to within a short distance (about $\frac{1}{8}$ inch) of the cutting surface as shown in the sectional view, Fig. 274. In this figure the clearance is exaggerated in order to illustrate the idea.

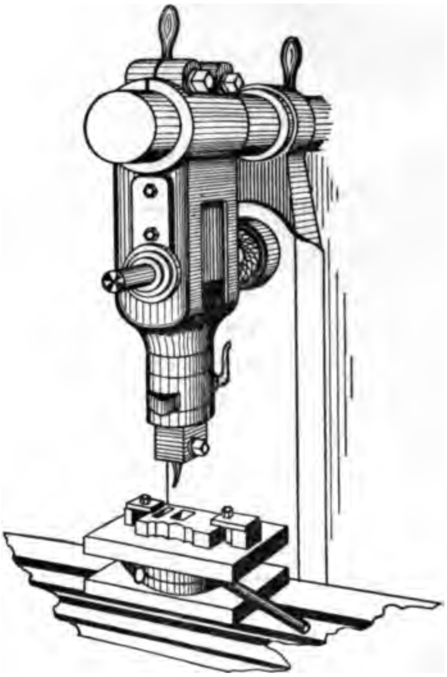


Fig. 266.

The walls of the upper part of the opening are at right angles to the base of the die, but they must be straight, that is, not crowning; because if the opening is wide enough to allow the punch to pass through the crowned part, the stock, if thin, would be likely to leave the blank with ragged edges which would extend up on the sides of the punch and have a tendency to burst the die.

Before hardening, the stripper and guide-screw holes should be drilled and tapped and the hole drilled for the gauge pin, or stop. If the name of the part to be punched, or the shelf number of the die are to be stamped it may be done now. After all screw holes, stop-pin holes, etc. are filled with fire clay mixed with water to the consistency of dough, the die is ready for hardening. Ex-

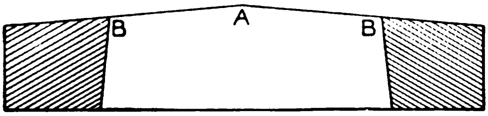


Fig. 267.

treme care should be exercised when heating a die for hardening: it should be no hotter than is necessary to accomplish the desired result, and the heat should be uniform throughout; the corners must be no hotter than the middle of the piece and the outside surface must be of the same temperature as the interior of the

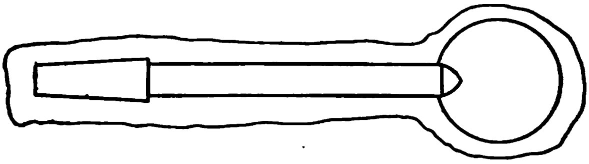


Fig. 268.

steel. The water in the bath should be slightly warmed to prevent any tendency to crack. The die should be lowered into the bath and swung back and forth gently so that the bath may pass through the opening, and harden the walls. As soon as the "singing" ceases it may be removed and plunged into a tank of

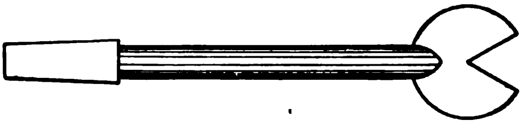


Fig. 269.

oil and allowed to remain until cold. It may then be brightened and the temper drawn. If more than a few minutes is to intervene between the time the die becomes cold, and commencing to draw the temper, it should be held over a fire or placed where it

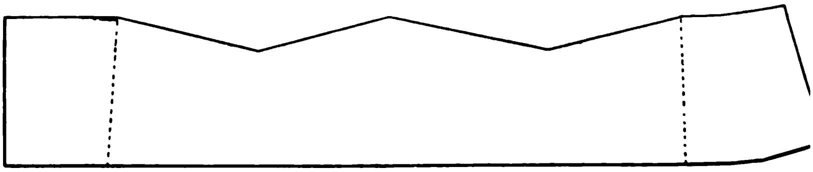


Fig. 270.

can be heated to remove the internal strains which have a tendency to crack the piece.

A very common method of drawing the temper of dies and similar pieces, is to heat a piece of iron to a red heat and place the hardened piece on it leaving the face of the piece uppermost. Experience has taught the writer, however, that this method of treatment is too harsh for hardened steel, especially if the job is in the hands of one not thoroughly experienced. One side of the piece is subjected to an intense heat while the opposite side is exposed to the cooling effects of the air. If an open fire is used a plate may be set on the fire, and the die placed on the plate before it is hot; now the temperature of the plate may be raised gradually, turning the die occasionally. In this manner the temper may be drawn to the desired degree with safety. When such a fire is not available two plates may be used, one heating while the other is in use. The first one should not be very hot, the next somewhat hotter, and so on until the die is drawn to the desired color.

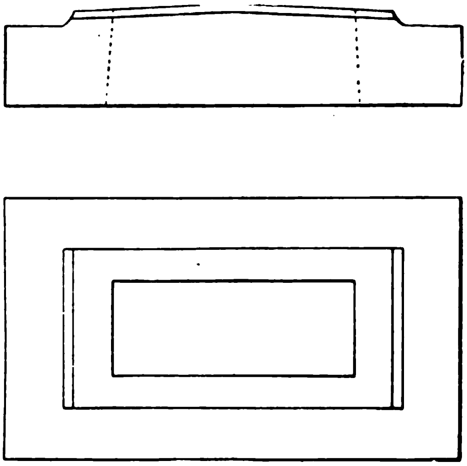


Fig. 271.

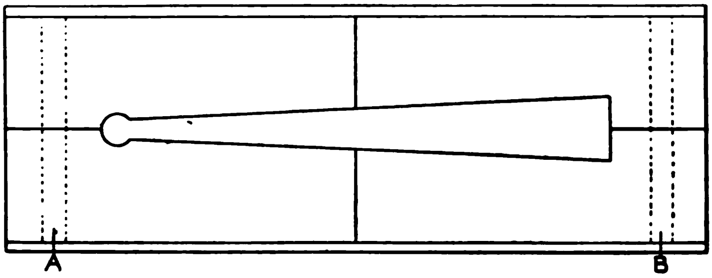


Fig. 272.

When a die of such a shape that is likely to give trouble, is to be hardened much more satisfactory results will follow if the "Pack Hardening" process is used. Run the dies from 1 to 5 hours in the fire after they are red hot, then dip in raw linseed oil.

THE PUNCH.

The punch is used to force the metal through the die thus producing pieces of the desired shape.

In the case of small plain dies the punch is generally made of the form shown in Fig. 275. The end A is of the same outline as the opening in the die, the shoulder B which bears against the shoulder of the punch holder takes the thrust when the punch is working. The shank fits the hole in the punch holder, or in the ram of the press.

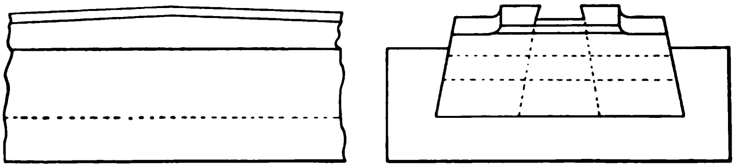


Fig. 273.

It is customary in most shops in this country to make the die to a drawing, or templet, and then harden it; after which the punch is fitted to it.

In the case of a punch for a plain die, the templet may be used in laying out the punch. If the shape of the opening in the die is the same on each side as shown in Fig. 276 and the die does not change shape in hardening the templet may be used either side next to the face of punch, but if the outline is of the form shown in Fig. 277, it will be necessary to exercise care when laying out the face of the punch from a templet, because the side of the templet placed against the face of the punch when laying it out will be opposite the one that would be placed against the face of the die when laying *that* out.

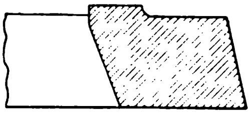


Fig. 274.

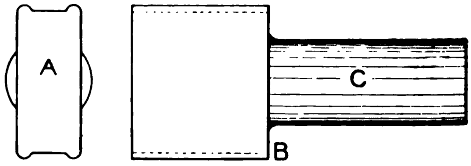


Fig. 275.

In order to obviate this trouble many tool makers lay out the face of the punch from the opening in the die before beveling the face for shear. In order to hold the punch and die together so that there will be no danger of the punch slipping while the required shape is being transferred, a die clamp of the form shown in Fig. 278 should be used.

The punch blank should be machined on both ends and the shank turned to size; the end which is to fit into the opening in the die should be finished with a smooth flat surface which should be colored with blue vitriol. After coloring, it may be clamped to the face of the die by means of the die clamp and the outline of the punch marked on the face by scribing through the opening in the die. This outline should be accurately marked with a sharp pointed prick punch as the scribed line is likely to become obliterated by the various operations of machining the punch to shape.

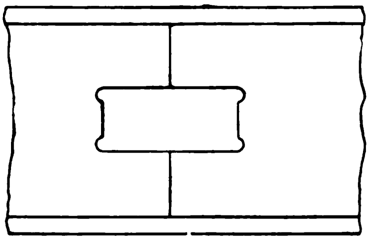


Fig. 276.

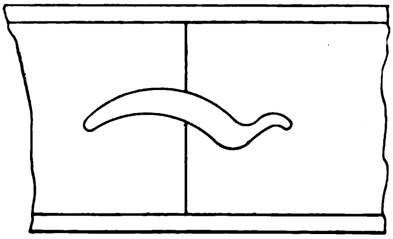


Fig. 277.

After the outline has been carefully prick punched, the punch may be milled or planed to shape leaving stock enough at all points to fit the die. If the die is to be beveled for shear, it should now be done and then hardened before fitting the punch.

The punch should be machined close to the lines and then placed over the hardened die and forced into it a little (about $\frac{1}{16}$ inch). This is termed "shearing in," and is the custom generally employed in this country.

After the punch has been sheared in for a short distance it may be removed and worked to size by means of chisel, file and scraper to the "witness" mark as the portion sheared in is termed, the operation of shearing may be repeated until the punch enters the entire length.

Fit of Punch and Die. If the material to be punched is thin or soft, it is necessary to make the punch a closer fit in the die than if the stock is heavy or very stiff. Thin stock requires a punch nicely fitted to the die in order to avoid ragged edges on the punched blank. When punching stock $\frac{1}{8}$ inch in thickness, the punch may be $\frac{1}{64}$ inch smaller than the die; if the stock to be punched is very stiff there may be a greater difference, however, the exact amount depends on the nature of the material to be used and the character of the tool.

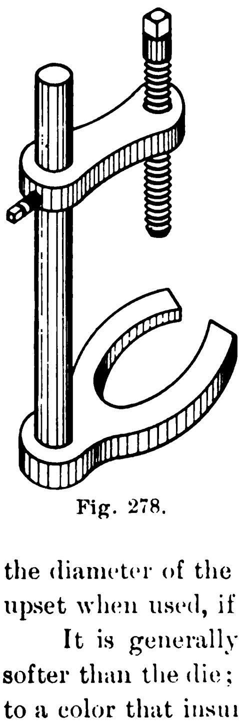


Fig. 278.

After the punch has been fitted to the die, the cutting end should be faced off to insure a good working surface and sharp edges. Any distinguishing names or marks necessary should be stamped on it, after which it is read for hardening.

Hardening the Punch. Punches are hardened by heating in a muffler furnace, or in a clear charcoal fire, to a *low red* and cooling in water or brine, preferably the latter. Punches whose form insures strength need be hardened only on the end; the hardening should not extend quite back to the shoulder or shank. Small, slender punches are sometimes hardened the *entire* length, especially if they are to punch stock nearly as thick as the diameter of the punch; in which case the punch would become upset when used, if it were not hard the entire length.

It is generally considered good practice to have the punch softer than the die; on this account the punch is generally drawn to a color that insures this result. If a die is drawn to a straw color, the punch is drawn until it assumes a distinct purple, or even a blue color.

The punch is sometimes left soft, not hardening it at all. When this is done, it can be upset, and refitted when worn. As this would not work satisfactorily in many cases, it can be advocated only when it would be considered advisable to use a *soft* punch.

It is sometimes necessary to punch a hole in a piece of work that has been machined to some given shape. The piece is placed on the face of the die against locating points, or in an opening in a gauge plate; the opening being of the same outline as the piece of work. In Fig. 279 is shown a blank intended for a gun-sight leaf; A shows the blank before the rectangular hole is punched, while B represents the leaf after punching. The hole is punched somewhat smaller than finished size, enough stock being left to work to size with broaches.

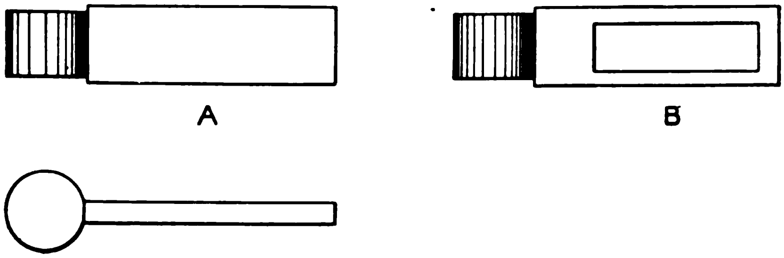


Fig. 279.

When punching work of this description, it is necessary to leave the face of the die flat; the punch is sheared as shown in Fig. 280. The piece punched from the leaf is of no value in this case, consequently the face of the punch is beveled, and the face of the die is left flat in order that the sight leaf may be straight after punching.

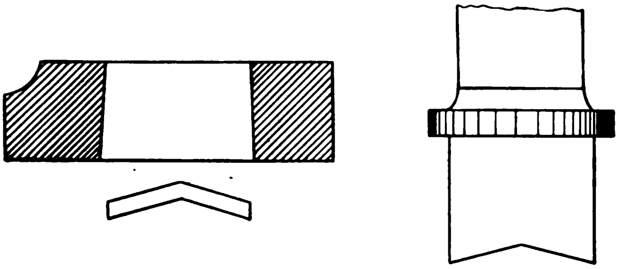


Fig. 280.

When a die and punch are to be used for an operation similar to the one described above, it is necessary to make a stripper of a form that allows the pieces to be easily placed in position and removed. As the piece which is punched is likely to increase in width from the operation, it is advisable to have stops or a guide on one side only in order to allow the piece to be readily removed after it is punched. Fig. 281 shows the same die with stripper and guide attached. The stripper is raised sufficiently from the die to allow the work to be readily inserted. A gauge pin is furnished for the end of the piece to determine the position of the slot in relation to the end. On one side is furnished a guide against which the piece rests to bring the slot central. The piece is held against the guide by means of a screw driver, a thin piece of steel, or a piece of wood.

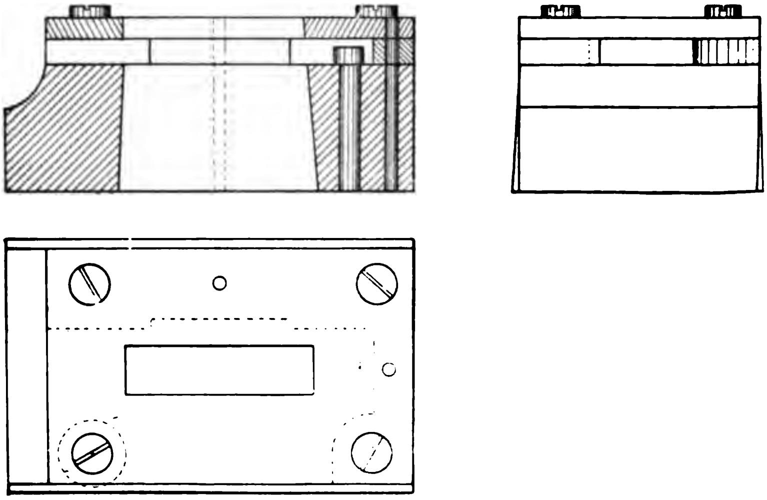
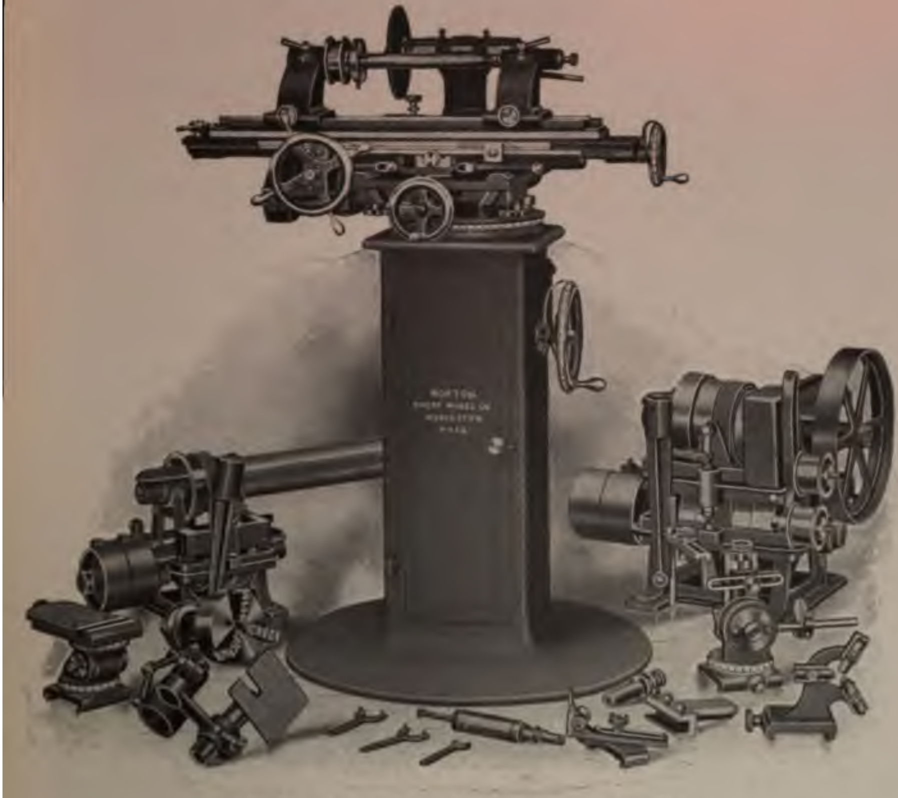


Fig. 281.

When a piece is to be punched and its size does not allow of a stripper being attached to the die as in the previous example, the stripper may be attached to the punch as shown in Fig. 282. It is made in such a manner that the stripper plate descending with the punch comes in contact with the piece being operated on and remains stationary. Between the stripper plate and the punch holder are coil springs which are compressed. The punches pass through and return. The stripper being forced downward by the action of the springs forces the blank from the punches. The gauge plate which is securely fastened to the d[illegible]



UNIVERSAL TOOL AND CUTTER GRINDER.
Norton Grinding Company.

by means of screws and dowel pins as shown, has an opening of the same general outline as the blank but somewhat larger in order that the blank may be easily put in place and removed.

GANG DIE.

The gang die is used when punching a blank, together with any holes it is necessary to have in the blank, without being obliged to handle the pieces twice as would be the case if they were "blanked" at one operation and the holes punched at another. Two operations would be necessary if a punch and die of the form shown in Fig. 282 were used.

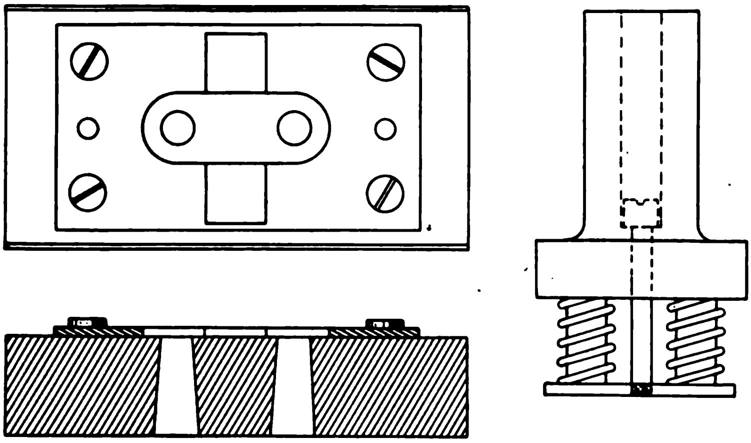


Fig. 282.

A common design of a gang die is shown in Fig. 283 which represents the piece operated on in Fig. 282. This die not only punches the holes but cuts the blank from the sheet. The stock is fed from right to left. The two holes are punched first and the stock is then fed along and the blank punched. At the same time the two holes are punched for the next blank to be cut. When the first two holes are punched in a strip of stock, the sheet is placed against the guide C, the end projecting slightly over the edge of the opening E. As the punches descend the holes F and F¹ are punched, and the end of the sheet is trimmed to length to stop at gauge pin D, which should be located about .010 inch farther to the left than the proper location for punching. The center pins as they enter the holes draw the stock back to the proper location. It is obvious that the punch A must be a trifle longer than the punches B^1 and B. Were the small punches longer than A or even of the same length they would hold the stock in such a manner that the centering pins could not locate it, and, again, the centering pins striking on one edge of the hole would spoil the blank punched and probably the pins

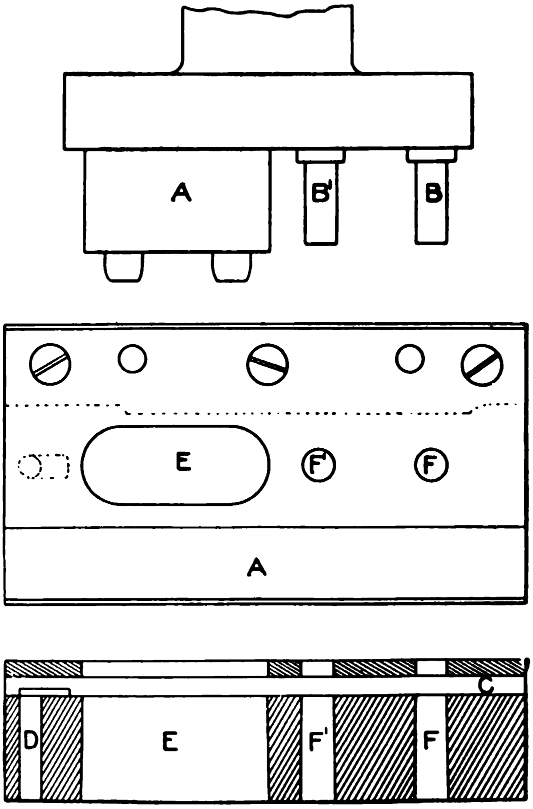


Fig. 283.

would be broken. The centering pins must not be a tight fit in the holes or the punched blank will stick to the pins and return with the punch. By carefully fitting the pins to a punched hole they may be fitted close enough to insure punching within a very small limit of variation. In fact for most classes of work it is possible to punch near enough to standards for all practical purposes.

When punching work with gang dies of the design shown in Fig. 283, it is easily seen that in the case of work being punched from strips wider than is necessary to get out two punchings, the scrap left between must be removed by some means. This is frequently done by a large lever shear, or a pair of power shears; this is a costly operation where many pieces are punched at a time. To do away with this extra cost, dies are made having an extra opening and a punch working into this cuts away the surplus stock, or scrap, leaving the edge of the sheet straight and in condition to rest against the guide. In Fig. 284 the opening A is the

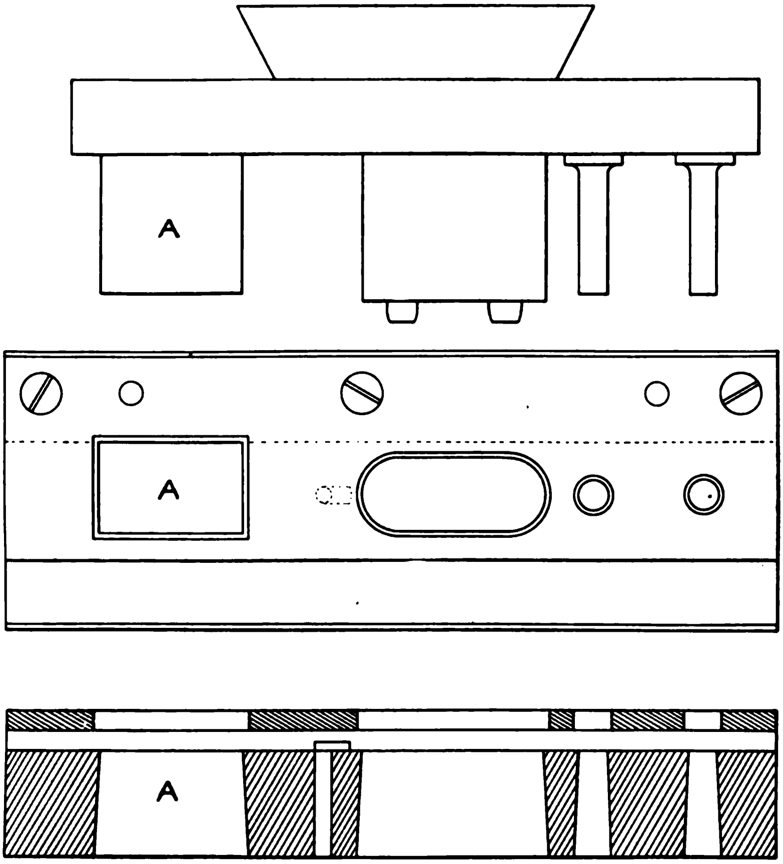


Fig. 284.

trimming die; the punch working in this cuts away the scrap leaving the edge of the sheet straight.

MULTIPLE DIE.

When making a die for punching pieces whose outline will allow it, it is sometimes advisable to make several openings of the same outline so arranged that as many pieces may be punched at a time as there are openings in the die block. If the work is punched in large quantities a great saving can be effected in the cost of production by the use of this form of die.

Where perforated sheet metal work is manufactured it is customary to make dies having as many as 500 punches working into one die block at a time, but as this is an unusual application of this principle it will not be considered.

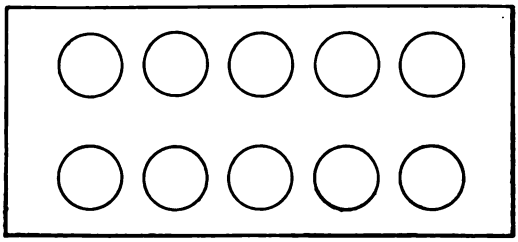


Fig. 285.

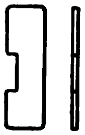


Fig. 286.

If it is necessary to punch 10 holes in the piece shown in Fig. 285 a die can be made having this number of openings. Then by making a punch holder having an equal number of punches properly located all the holes can be punched at one stroke of the press.

While in the case just cited the piece of stock which had the holes punched in it is the product, the punchings being scrap, the same principle may be applied to punching blanks from a sheet of stock by means of a multiple die.

The design shown in Fig. 286 is the product in a shop where many thousands of this piece are used monthly. The die produces a dozen or more blanks at each stroke of the press; but for convenience in illustrating the die and punches, it shows but four openings in the die with a corresponding number of punches. See Fig. 287.

If a die were made with the openings near enough together to punch the stock as shown in Fig. 288 there would be so little stock between the openings that the die would not stand up when used; for this reason the openings are located in such manner that every other opening shown in Fig. 288 is omitted. When the punch descends four blanks are punched; the stock is moved until the first opening strikes the gauge pin. This leaves the stock in position to punch between the openings already made, thus preventing waste. The next time the stock is moved until the gauge pin strikes the wall of the last opening to the right.

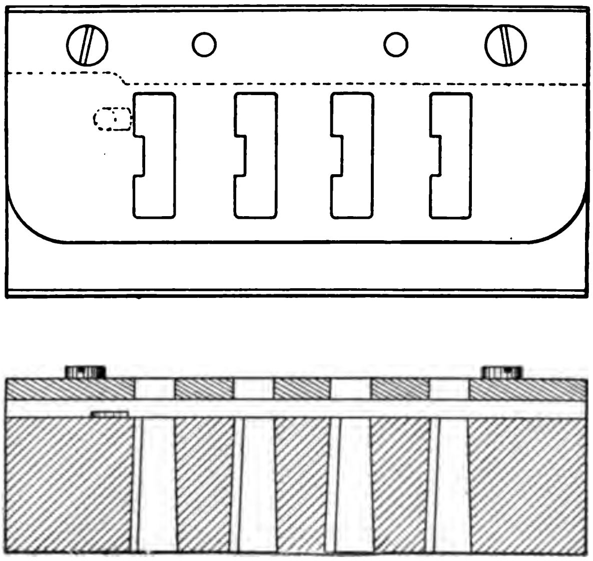


Fig. 287.

BENDING DIE.

In order to bend metals to various forms, dies are made for use in punching presses, drop hammers and various other machines. A simple form of bending die is shown in Fig. 289. The shape of the upper and lower parts of the die is such, that when the upper part is brought down on the blank B (shown by the dotted lines) it will be bent to the required shape. The shoulder A forms a locating stop against which the blank rests before bending.

When making bending dies for extremely soft metals, the dies may be made of the exact shape of the model, or the shape the piece should be when finished; but if the pieces are made from stiff material which bends with difficulty, it will be necessary to make the die of a form that will give the article **more** bend than is required as it will spring back some as soon as released by the return of the upper part.

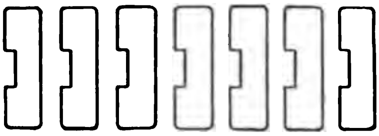


Fig. 288.

Compound Bending Die. In Fig. 290 is shown a form of bending die used in bending bow spring and looped wire for armature connections or other looped wire work. The work is placed in the die, and the punch, as it descends, bends the wire to the shape of the die. The spring just back of the punch is compressed thus allowing the punch holder to descend and force the side benders BB toward the punch by means of the wedge pins AA, thus forming the piece in a circle.

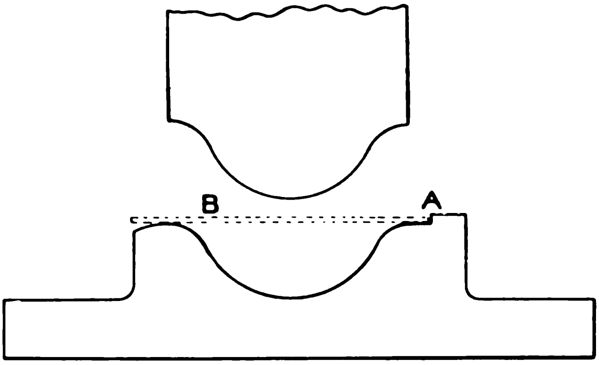


Fig. 289.

It is obvious that it is necessary to make the shape of the punch and die different. The lower die must have its bending surface, a curve of a radius equal to that of the punch plus the thickness of the material.

FORMING DIE.

This type of die is familiarly known as a *drawing die.* The most common examples of *forming* die is that used for drawing a flat circular blank, as shown at A, Fig. 291, into a cup-shaped piece, as shown at B. This operation can be done in an ordinary punching press by means of a forming die of the shape known as a push through die, from that fact that the piece is formed to shape, and pushed through the die at one operation. This form of die is shown in Fig. 292. The face of the die is cut to receive the blank; this depression is known as the *set edge*. The opening in the die is given a "draw" of ¼ to ½ of a degree making it larger at the top, the upper edge is rounded over and left very smooth. The bottom edge of the opening is made very sharp in order that the piece may not be carried back with the punch as it returns.

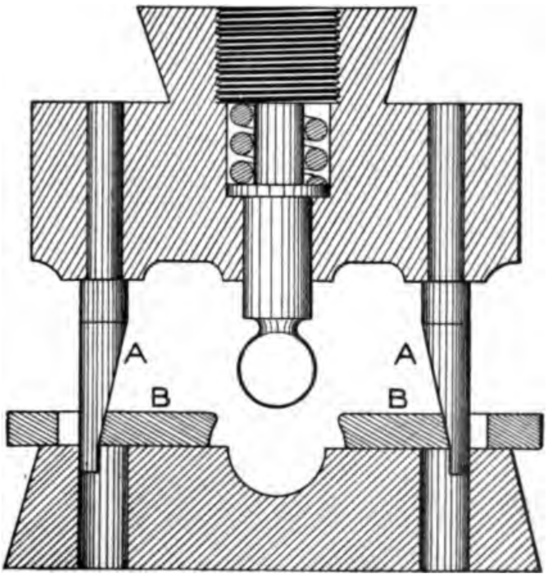


Fig. 290.

This form of die is left as hard as possible, and the walls of the opening are made as smooth as they can be polished. It is sometimes advisable to finish the walls with a lateral rather than a circular finish.

MAKING GAUGES.

Gauges are used in machine shops in order that a part of a machine, apparatus, or tool may correspond with some other part, so that when it is assembled every part may go in its place with little or no fitting.

In shops where work is made on the interchangeable plan, that is, a piece of work made to-day will exactly duplicate a similar piece made at some time in the past, a very thorough system of inspection is necessary. In order that the inspection may accomplish the desired result, gauges are made that show any variation of the pieces from a given standard.

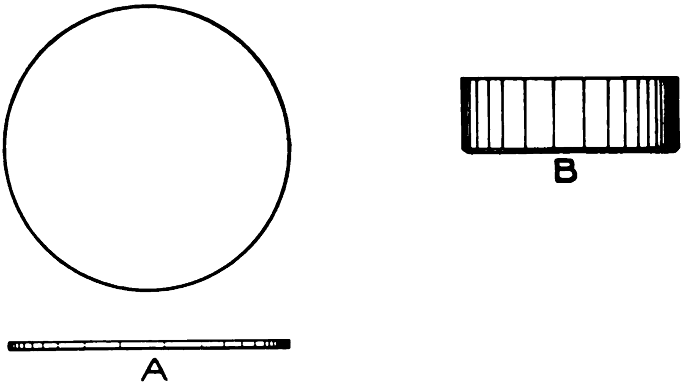


Fig. 291.

There are several forms of gauges in use for various classes of work, but only those in common use in the general machine shop will be considered here.

Gauges are generally made of *tool steel*; but *hardened tool steel* has a tendency to change its size or shape at a considerable time after the hardening takes place. This change is ascribed by acknowledged authorities, to a rearrangement of the minute particles or molecules of the steel, whose original arrangement had been changed by the process of hardening. While this change of size or shape is small, so small indeed, that it need not be considered except in the case of gauges where great accuracy is required, yet it has led some manufacturers to use machinery steel.

If tool steel is used, the tendency to change its shape may be overcome to some extent by grinding the gauge to within a few thousandths of an inch of finish size and allowing it to "season" as it is termed among mechanics; that is, it is laid aside for a few months or a year before finishing to size. This method is open to serious objection if one is in a hurry for a gauge.

To save time, it is customary in many shops to draw the temper to a straw color, allowing the gauge to cool off slowly; this operation is repeated several times. It is necessary to brighten the steel each time before drawing the temper in order that the colors may be readily seen; as this very materially softens the gauge it will not last as long as if left hard.

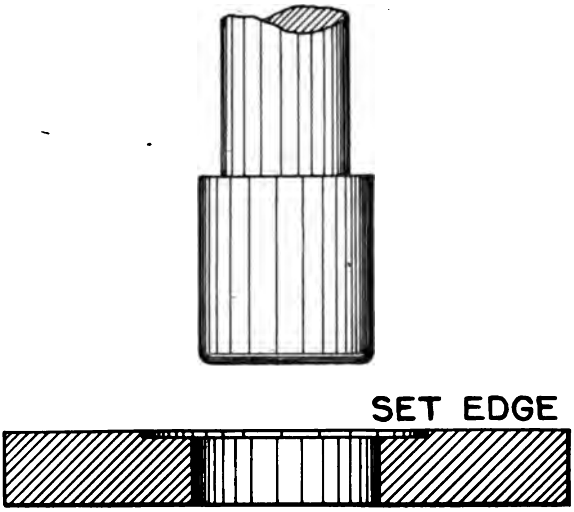


Fig. 292.

Accuracy in Gauge Making. When making gauges the workman should observe the points emphasized under "Approximate and Precise Measurements." While gauge making is generally considered very accurate work, unnecessary accuracy should not be used. If a gauge is intended for work where a variation of .005 inch is permissible, it is folly and a needless waste of time to attempt to make the gauge within a limit of variation of .0001 inch. On the other hand if the gauge is to be used as a test gauge on work requiring *great accuracy* it is necessary to use every possible effort to make it accurate.

If a gauge is to be made of tool steel, it is necessary to first remove all the outside portion (skin) of the stock, and "block" the gauge out some where near to shape; it should then be thoroughly annealed. If the gauge is flat, and should spring while annealing it *should not* be straightened cold, as it would be almost sure to spring when hardened.

It is necessary to stamp the name of the part to be gauged and the sizes of the different parts of the gauge. The workman should bear in mind that the effect of driving stamps, letters, or figures into a piece of steel will be to "stretch" it, consequently it is advisable to stamp the gauge before finishing any of the gauging portions to size, even if the gauge has an allowance for grinding.

PLUG AND RING GUAGE.

Plug gauges are used to gauge the size of a hole, while a ring gauge is for measuring a cylindrical piece of work.

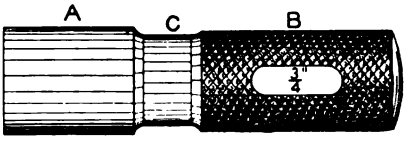


Fig. 293.

To make a plug gauge as shown in Fig. 293, stock should be selected enough larger than finish size to allow for turning off the decarbonized surface. After roughing out, the handle B should be turned to size and knurled, the portion C should be turned to size and finished, the spot in the center of the handle should now be milled and the size of the gauge and any distinguishing mark or name of the article to be gauged should be stamped as shown. Or, as is the custom in many shops, the stamping may be done at C. After stamping, the gauge end A may be turned to a size .010 or .015 inch larger than finish to allow for grinding. Plug gauges should be heated very carefully for hardening, remembering that the lower the heat, the more compact will be the grain, and a piece of steel whose grain is fine and compact will wear better than one whose grain is coarse. If the gauge is one requiring great accuracy, it may be left .0025 or .003 inch above size and allowed to season, provided this precaution is deemed necessary; if not it may be ground to a size .001 inch larger than finish, after which it must be lapped to finish size. When grinding a gauge of this description, it is advisable to use a grinding machine having a supply of water running on the work to keep it cool, but if this form of grinder is not available, the gauge should not be heated any more than is necessary. The gauge should be measured while cold, as steel always expands from the action of heat, and a gauge ground to size when heated would be too small after it had cooled.

When grinding work of this nature, it is advisable if possible to use a form of grinder having two dead centers, that is, one in which neither center revolves. This is mentioned on account of the tendency in some shops where there is no universal grinder, (and an engine lathe is to be used as a grinder) to select the poorest lathe in the shop for the purpose. Lathes that have been in use for some time are very likely to have become worn, so that accurate work is impossible; this is especially true of the head spindle which will duplicate its untruth on the piece being ground.

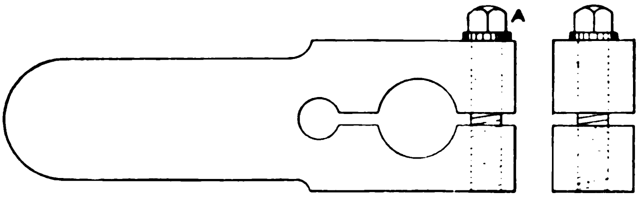


Fig. 294.

If obliged to use a machine of this description, it is advisable to leave a trifle more stock for lapping than if a suitable grinder is at hand. When grinding, a coarse wheel free from glaze should be used to grind within .004 of finish size, after which a finer wheel may be substituted to grind to lapping size.

A very simple method of making a lap for lapping a cylindrical surface is shown in Fig. 294; this consists of a piece of cast iron having a hole bored a trifle larger than the size of the gauge to be ground. It is split as shown, and is closed by means of the screw A.

If there is much gauge, or similar work, requiring lapping it is advisable to make a lap as shown in Fig. 295. The holder A has a hole bored to receive the laps which are made in the form of rings fitting the holder as shown; these rings are split in three places. One cut is carried *through* one wall, while the other two commencing at the inside, terminate a little distance from the outside surface. The laps may be held in place by means of the pointed screw shown at B.

The lapping should be done with flour emery mixed with oil. This operation has the effect of heating the gauge to a degree that would make it unsafe to caliper. On this account it is necessary to have a dish of water handy in which to cool the gauge before measuring it. This water should not be *cold*, or incorrect measurements will result; it should be as nearly as possible the average temperature of the room in which it is to be used, (about 70 degrees).

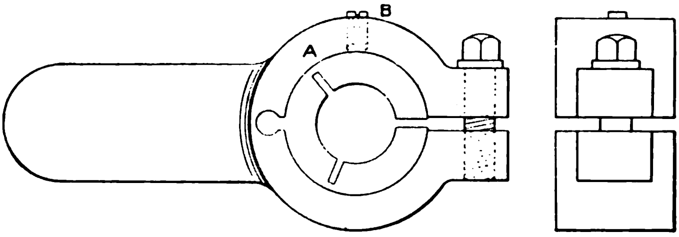


Fig. 295.

When plug gauges are made of machinery steel they should be case hardened in the following manner. They may be packed as for "Pack Hardening"; that is, using charred leather as the packing material. They should run in the furnace for 7 or 8 hours; *after* they are red hot, the box should be taken from the furnace and allowed to cool, after which the gauge may be heated in an ordinary fire enclosing it in a piece of tube. When it reaches a low red heat, it should be plunged in a bath of raw linseed oil. It will not be necessary to draw the temper, and the danger of alteration as it ages is done away with.

The reason for not hardening when the gauge has run the required length of time in the furnace is that the effect of the *second* heat is to refine the steel, making the grain more compact, like *properly* hardened *tool steel*, thus increasing its wearing qualities.

After the gauge has been lapped to the required size, it may be placed in a chuck on the grinding machine and the end ground off to remove any portion that is slightly smaller than the balance of the gauge, as the lapping is likely to grind the extreme end slightly tapering. In order to save time when grinding the end, the gauge may be made as shown in Fig. 296. The sectional view shows the end cupped in, leaving a wall $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick according to the size of the gauge, the larger sizes having the thicker walls; the cupping should be about $\frac{1}{16}$ inch deep and the corner left slightly rounded as shown.

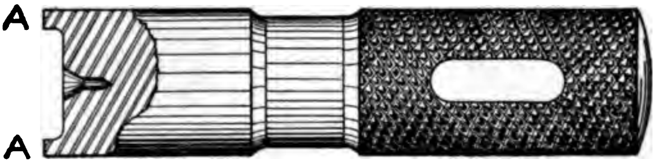


Fig. 296.

Another method is to cut a groove with a round nose cutting off tool leaving a disc on the end as shown in Fig. 297. If the gauge has its end shaped as shown in Fig. 296, the projecting end A A is ground away until the end of gauge is straight across. In case it is made as shown in Fig. 297, the disc A is broken off and the end ground as described.

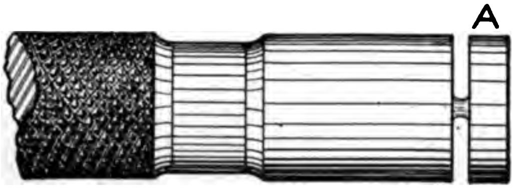


Fig. 297.

RING GAUGE.

Ring gauges intended for gauging cylindrical pieces smaller than 1 inch diameter are generally made of a solid piece of tool steel, or machinery steel which may be case hardened. For a gauge 1 inch or larger custom varies, some tool makers making it of a solid piece, while others make the body of cast iron, or machinery steel, into which is forced a hardened bushing which is the gauge proper.

It is advisable when making a solid gauge to use a piece of steel somewhat longer than finish dimensions as shown in Fig. 298. The dimension A representing the *finish* length of gauge; the projections B B being left until the gauge is lapped to size. The hole should be bored somewhat smaller than finish size in order to allow for grinding and lapping. If a grinder having an internal grinding attachment is not available, the allowance should be much less than if it were possible to grind the walls of the hole. If the gauge is to be ground to size an allowance of .005 inch will be sufficient; if not to be ground and the hole is bored straight and smooth, allow .0015 to .002; but the amount left cannot be given arbitrarily, as much depends on the condition of the hole, and the care used in hardening.

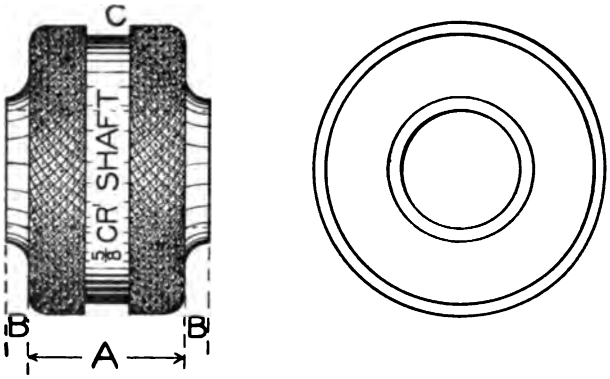


Fig. 298.

After boring the hole the blank may be placed on a mandrel the ends shaped as shown in Fig. 298, the outside diameter turned and knurled, and the portion C necked to the bottom of the knurling. The size and any distinguishing marks may be stamped on this necked portion as shown. The gauge is now ready for hardening; much better results may be obtained if the gauge is pack hardened. If this method cannot be used, the gauge should be carefully heated in a muffler furnace or in a piece of gas pipe or iron tube in an ordinary fire. When it reaches a *low uniform* heat it should be plunged in a bath of brine and worked around so that the bath may circulate freely through the hole; excellent results can be obtained if a bath is used having a jet of brine or water coming up from the bottom and passing through the hole with some force in order to remove any steam that may be generated.

If it is considered necessary to allow the gauge to "season," the hole may be ground enough to remove part of the allowance, and the gauge laid away. If it is not considered necessary to do this it may be ground .001 or .0015 inch smaller than finish size to allow for lapping.

When lapping a ring gauge to size, it is necessary to use a *suitable* lap. A poor lap is the cause of many of the failures when attempting to do satisfactory work of this description.

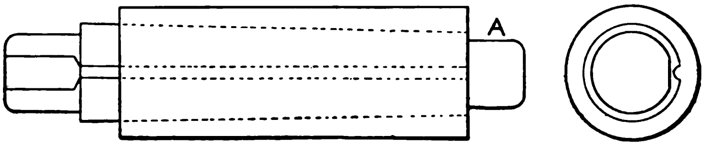


Fig. 299.

When a grinder having an internal grinding attachment is not available, and it is found necessary to leave considerable stock in the hole for lapping, many tool makers claim best results from using two laps; the first, a lead lap, for removing most of the stock; and the second, a cast-iron lap for finishing the hole to size. In either case, the lap should be in the form of a shell which should be held on a mandrel when in use. Fig. 299 shows a lead lap on a mandrel as described.

The mandrel should be made with the ends somewhat smaller than the body which should be tapering in order that the lap may be expanded as it is driven on. A groove is cut the entire length of the body with a convex milling cutter, or it may be cut in the shaper or planer, holding the mandrel between centers, or in the vise, cutting the slot with a round-nosed tool. A mold for casting the lead to shape may be made of two pieces of wood an inch or two longer than the desired length of lap which should be three times the length of the hole in the gauge. The two pieces of wood should be clamped together, and a hole bored with a bit about $\frac{1}{8}$ inch larger than the diameter of the finished lap; after boring to the required depth, a bit should then be used the size of the projection on the small end of the mandrel; the hole bored with this bit should be a trifle deeper than the length of the projection. After the hole has been bored in the mold as described, the mandrel may be put in position as shown in Fig. 300 with the mold in a vertical position. Two narrow strips of wood or metal are placed on top of the mold to hold the mandrel central in the mold. In order that the lead may *run* well, it will be necessary to heat the mandrel somewhat; this should be done before putting it in the mold.

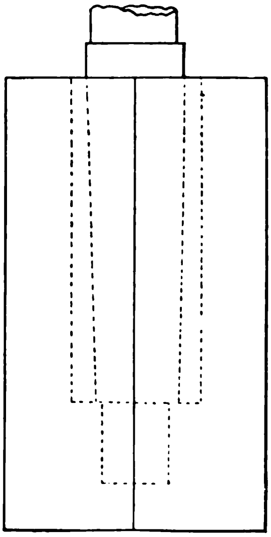


Fig. 300.

After the lead has become cool the mold may be opened, and the casting removed. It should be placed in the lathe on the mandrel, and turned to a size .001 inch smaller than the hole in the gauge; it may then be charged with emery, using fine emery and oil.

For finishing the hole to size, or lapping a hole *ground* nearly to size, it is advisable to use a lap made of harder material than lead; for this purpose fine-grained cast iron answers admirably, although copper is preferred by some. In order to make a cast-iron lap, a mandrel is necessary, which should taper $\frac{1}{8}$ to $\frac{3}{16}$ inch per foot of length. The slight taper is used in order that the lap may not increase its size too rapidly when driven on the mandrel. The cast-iron lap (sleeve) should be bored with a taper corresponding to the taper of the mandrel, after which it may be forced on the mandrel and turned to size and split as shown in Fig. 301. One slot should extend through the wall as shown at A (end view), while the other two slots B B extend deep enough to allow the lap to expand readily. Before finishing the hole to size the lap should be forced a trifle farther on the mandrel, and

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ASTOR, LENOX AND
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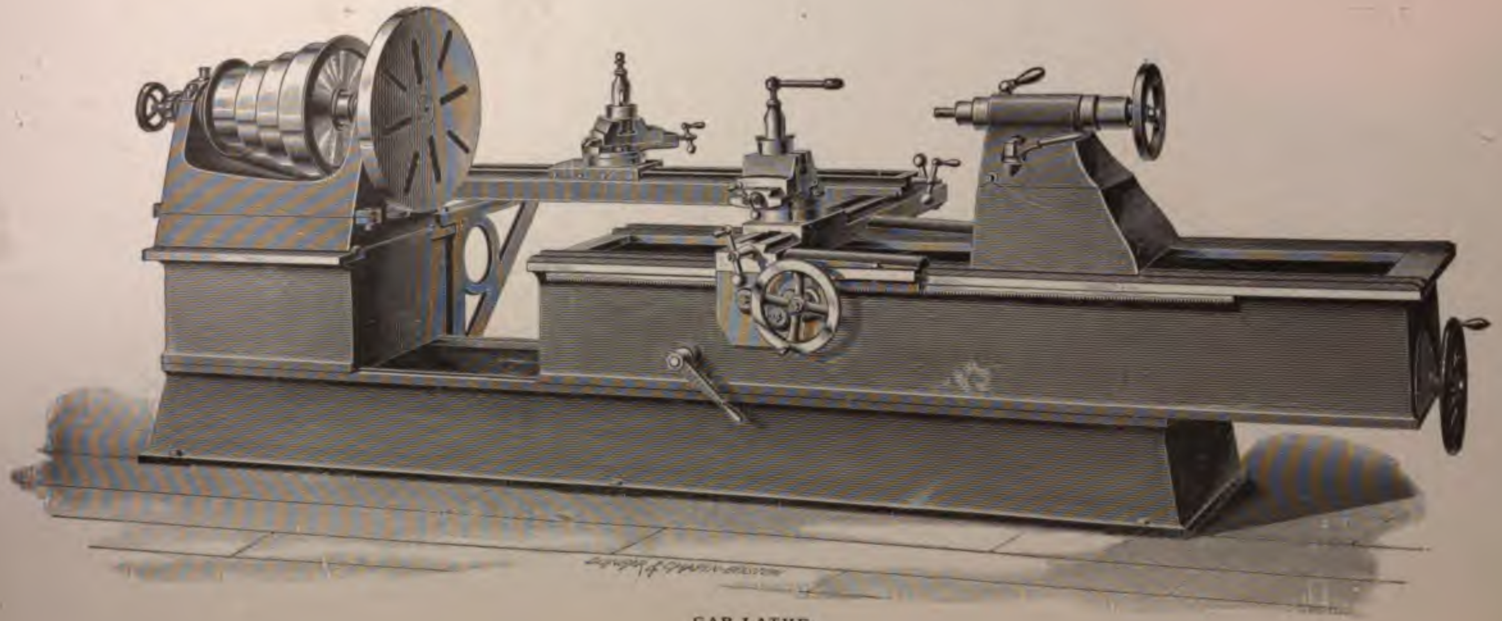

GAP LATHE.
Fay & Scott.

trued in the grinder using an emery wheel to cut the lap. The lap should be *perfectly round* and *straight*, in order to produce true holes. For the finish lapping the finest of flour emery should be used. The same precautions should be observed while cooling the gauge before trying the size of hole, as were noted under "Lapping Plug Gauges." In order to clean the gauge of the oil and emery, it should be dipped in a can of benzine, which readily removes any dirt. Extreme care should be exercised when washing work in benzine that it is not brought in the vicinity of a flame of any kind, as it is *extremely* inflammable, and very difficult to extinguish if it becomes ignited; should it become ignited it can be extinguished with a piece of heavy sacking.

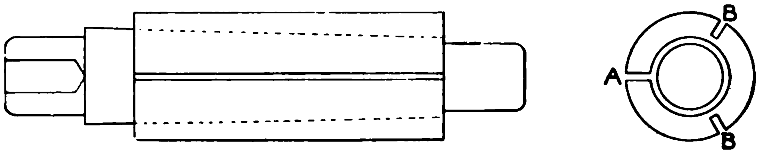

Fig. 301.

The ring should be fitted to the plug gauge which has previously been finished to the correct size. It must be borne in mind that the temperature of the plug and ring should be as nearly the same as possible when testing.

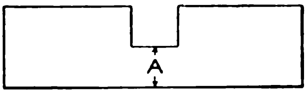

Fig. 302.

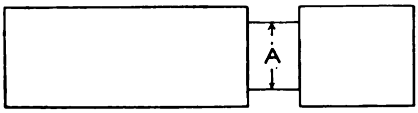

Fig. 303.

SNAP GUAGE.

This form of gauge is used more extensively than any other for outside measurements; it is extremely useful in gauging a dimension between two shoulders as shown at A, Figs. 302 and 303; in the former case the piece being machined is flat while in the latter it is cylindrical.

Snap gauges may be designed to meet the requirements of the particular piece of work upon which they are to be used. When a gauge of this description is intended for use on a cylindrical piece, the opening should be made a trifle deeper than one-half the diameter of the piece to be measured.

When a snap gauge is intended for flat work, the depth of the slot depends on the nature of the work.

Snap Guages for Cylindrical Work. As previously stated when snap gauges are to be used for gauging cylindrical pieces it is necessary to make the opening a trifle deeper than one-half the diameter of the piece to be measured, as shown in Fig. 304, in which A represents the cylindrical piece to be gauged.

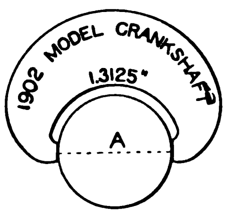

Fig. 304.

When making a snap gauge of this form the stock should be blocked out somewhere near to shape and annealed; after annealing the sides may be made flat and parallel, and the size and any distinguishing marks stamped as shown, after which the gauge part may be worked to a size .008 to .010 inch smaller than finish to allow for grinding. The outer edges should be rounded somewhat to prevent cutting the hands of the operator.

When hardening gauges of this type, some tool makers harden only the prongs that come in contact with the work, while others harden the entire gauge. If the contact points alone are to be hardened, the heating can best be done in a crucible of red-hot lead, but if this is not at hand a piece of flat-iron may be placed each side of the gauge, allowing the ends to be hardened to project beyond the pieces; the whole may now be grasped in a pair of tongs, and placed in the fire. The points will reach a hardening heat before the portion between the flat pieces is very much heated. It may be plunged in water or brine to harden.

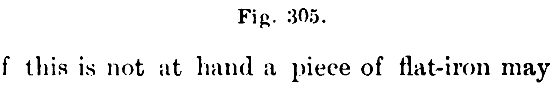

Fig. 305.

If it is considered advisable to harden the gauge all over, it should be heated very carefully in the fire, making sure that the blast does not strike it; turn it frequently to insure a uniform heat. When it reaches a low red heat remove from the fire and plunge in the bath; if the gauge is quite thin a bath of oil will harden sufficiently; if it is dipped in water or brine the bath should be warmed somewhat in order to avoid as much as possible any tendency to spring.

After hardening, the gauge is ground to a size .0005 inch smaller than finish and lapped to size; the method used in grinding gauges of this character will be described later.

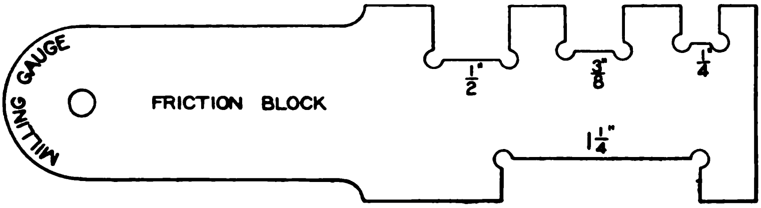

Fig. 306.

In order to be able to give gauges the correct size, it is often necessary to make male gauges. The simplest form of male gauge is shown in Fig. 305; it is a flat piece of tool steel, made slightly small on one end to avoid grinding to size the entire length. After hardening the large end, it is ground to size; it is then ready for use in testing the size of the female snap gauges while the latter are being lapped to size; or when grinding if lapping is not considered necessary. When it is necessary to make a snap gauge for gauging two or more dimensions on a piece of work, the gauge may be made as shown in Fig. 306, while Fig. 307 represents the piece to be gauged.

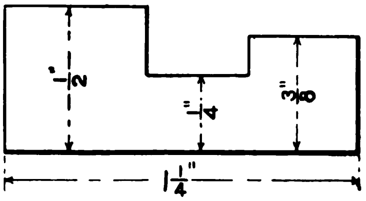

Fig. 307.

After cutting off the steel for the gauge, the sides may be planed to remove the "skin." One of the flat surfaces may be colored with blue vitriol, or it may be colored by holding over a fire until the surface becomes blue. The handle and the openings that constitute the gauges may be laid off on the surface. After milling the handle to shape the holes shown at the corners of the openings may be drilled; these holes facilitate the operations of filing and grinding, particularly the latter. The openings may be milled or planed to a size somewhat ($\frac{1}{32}$ inch) smaller than finish and the gauge is ready for annealing. After it is annealed the two flat surfaces may be planed or filed until flat and parallel. The name of the piece to be gauged and the size of the openings may be stamped as shown. If the gauge is intended for gauging work where a few thousandths of an inch either way would make no particular difference, it is customary to make the openings to the given sizes before the gauge is hardened. However, if the gauge must be exact to size, it is necessary to leave from .003 to .005 inch on each measuring surface to allow for grinding, and if it is desirable to have the gauge retain its exact size for any considerable length of time, it will be found necessary to finish the gauge to size by lapping *after* it is ground.

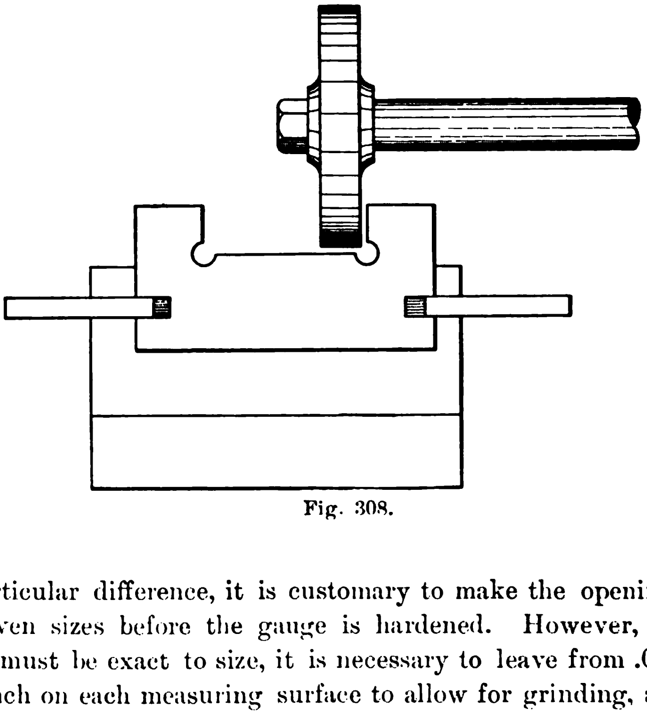

Fig. 308.

Grinding Snap Gauges. Snap gauges may be held in a vise on the universal grinder when grinding the openings to size provided the gauge is held in such a manner that it cannot spring. If it were sprung in any manner while being held, it would assume its normal shape when taken from the vise, and consequently the measuring surfaces would not be parallel. This would destroy the accuracy of the gauge, as it is highly important that the measuring surface of the opening be parallel.

A snap gauge may be clamped to an angle iron which may be held, while grinding, in the vise as shown in Fig. 308, or it may be clamped to a piece of machinery steel or cast iron which is centered as shown in Fig. 309. This holder should be placed between the centers of the grinding machine.

If the opening whose gauging surfaces are to be ground is of sufficient width, an emery wheel of the form shown in Fig. 310 may be used, or a wheel may be recessed on its sides as shown in Fig. 311. If a wheel of the form shown in Fig. 310 is used it will be necessary to remove the wheel after grinding one wall of the opening and reverse it to grind the other. If, however, the opening is too narrow to allow a wheel of the form shown above to be used, a very thin wheel may be made to answer the purpose, but it will be necessary to swivel the head of the grinder a little in order that the wheel may touch the surface to be ground only at the corner of the wheel.

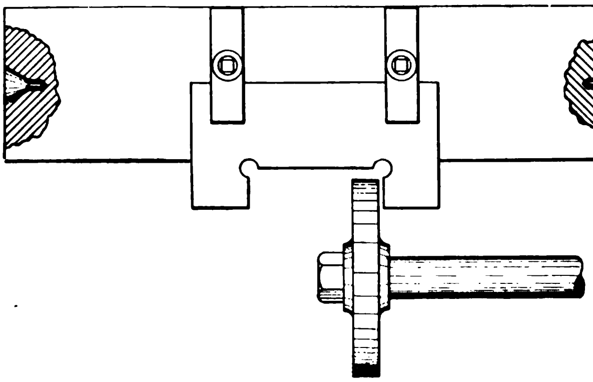

Fig. 309.

If a grinding machine is not available, an engine lathe or a bench lathe can be used. If the lathe is provided with a grinding attachment, the holder to which the gauge is attached may be placed between the centers of the lathe, and the grinding attachment used in the ordinary manner. If the lathe is not provided with a grinding attachment the emery wheel may be mounted on an arbor between the centers of the lathe. The arbor may be driven from any accessible pulley either on some overhead countershaft or some machine having a pulley in line with a small pulley on the arbor, on which the driving belt is supposed to run. If this method is used it will be necessary to have hardened centers in both head and tail spindles. If a *thin* wheel is used in grinding the surfaces of a narrow opening, the tail center of the lathe may be set over each way to give the desired amount of clearance to the side of the emery wheel. The holder mentioned may be fastened to the tool rest, or the gauge may be fastened to the rest as shown in Fig. 312. At the right is shown a side view of one of the clamps used in holding the work to the rest while grinding; the center is represented as being cut away in order that it may bear at its ends thus removing any chance of its tipping the work being ground.

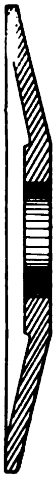
Fig. 310.

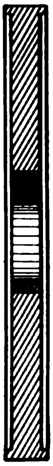
Fig. 311.

Lapping a Gauge to Size. Where it is essential that gauges retain their exact size for a considerable length of time, the gauging surfaces must be lapped to size after grinding. The surface left by the emery wheel, even when the utmost care is used, consists of a series of small ridges or irregularities which wear away as the gauge is used and leave the opening too large; lapping the gauging surfaces with oil and emery grinds these minute particles away, leaving a perfectly flat surface, thereby increasing the durability of the gauge.

A convenient form of lap for use in lapping the gauging surfaces of snap gauges is shown in Fig. 313. It consists of a piece of copper or brass wire, bent as shown; the surface A is filed or hammered flat and charged with some abrasive material, as emery; extreme care must be used in lapping the surfaces that they remain perfectly flat and parallel. Unless the operator has had considerable experience in this particular branch of the business, he will be likely to cut the edges away more than the center. To avoid doing this, pieces of hardened steel may be clamped to each side of the gauge before grinding, as shown in Fig. 314. As the tendency when lapping is to make the outer edges round, the portions rounded will be the edges of the pieces clamped to the gauge. After the gauge has been lapped to size these pieces may be removed.

Adjustable Snap Gauge. Snap gauges that are in *constant* use soon wear to an extent that renders them useless, making it necessary to close them in and grind and lap them to size again, or else replace them with new gauges. This tendency to wear and the consequent labor and cost of resizing or replacing has caused the adoption of a style of snap gauge whose size could be altered when necessary; this form of gauge is styled an adjustable snap gauge.

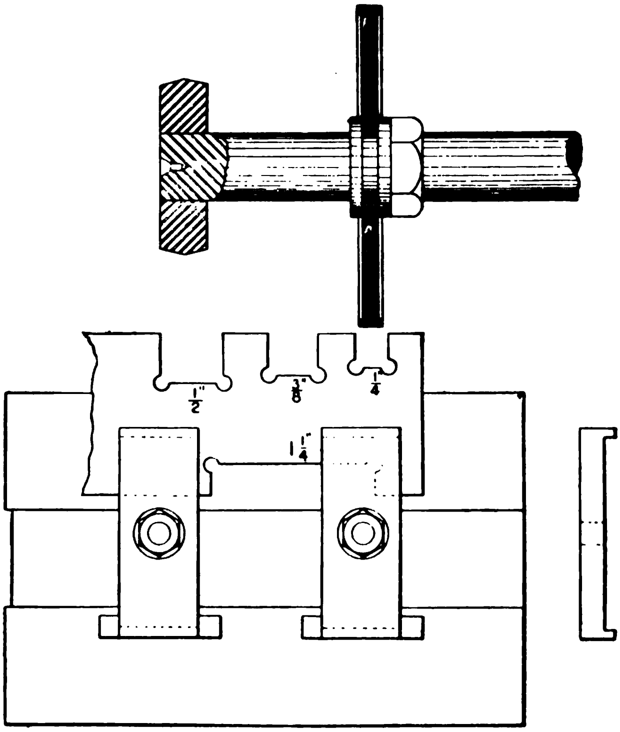

Fig. 312.

The method of adjustment differs in different shops. Fig.

815 represents a form of adjustable snap gauge which is not expensive and gives excellent results in that its size may be readily adjusted. After blocking out the gauge somewhere near to shape, the screw hole for the adjusting screw C should be drilled and tapped, and the slot milled for the adjustable jaw. The jaw should be made as shown having a slot through which the binding screw D may pass. The jaw should fit snugly in the slot in the frame and placed in position after stamping the name and any distinguishing marks. The aperture E should be worked to a size .010 or .015 inch smaller than finish. The adjustable jaw B may now be removed and the gauging (or contact) surface hardened, being careful not to harden the entire length of the large portion or a crack may appear in the sharp corners on account of the unequal size of the two portions. In order to heat the contact surface and not heat back into the sharp corners, the face may be immersed in red-hot lead, leaving just long enough to sufficiently heat the face; or the smaller portion may be held in a pair of tongs letting the end of the jaws come against the shoulders of the piece. It may then be heated in a gas jet or ordinary fire. For most purposes it will not be necessary to harden the gauge all over; if the gauging portion A is hard

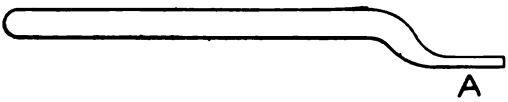

Fig. 313.

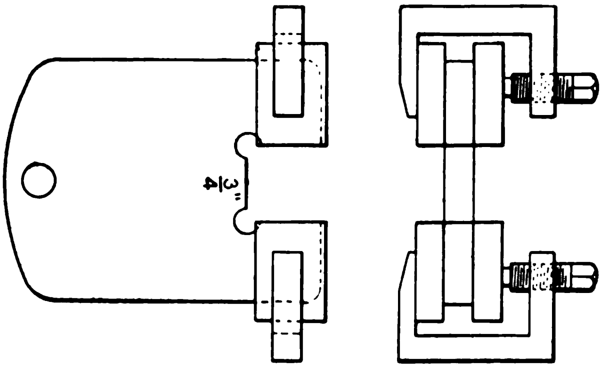

Fig. 314.

ened it will be found sufficient. After hardening, the gauge may be assembled and ground and lapped as already explained.

LIMIT GAUGE.

Where it is not necessary that work be of exact size, and a small limit of variation is permissible, limit gauges are used. They prevent a waste of time in attempting excessive accuracy, yet leave the work so that the corresponding parts when brought together will fit well enough to meet requirements.

These gauges are also valuable in roughing work for finishing.

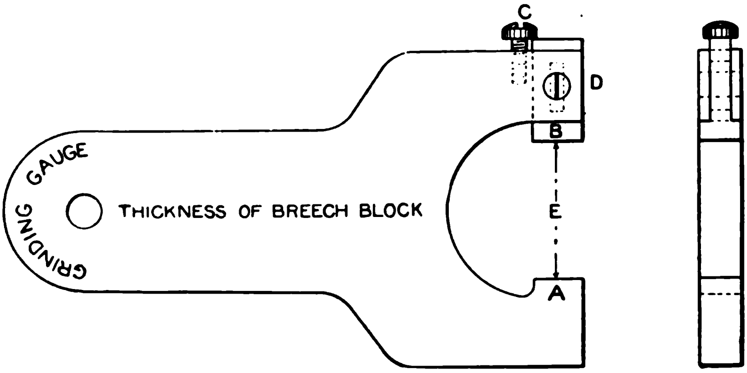

Fig. 315.

When so used practically the same amount of stock is left on each piece, thus facilitating the finishing process.

If a cylindrical piece is to go in a reamed hole, and the piece fits well enough for all requirements when .003 inch smaller than size of hole, it is folly to spend the time necessary to get a more accurate fit.

The amount of variation allowable must be decided in each case; on one job a limit of variation of .001 inch might be all that could be allowed, while on another piece of work .010 inch might be allowable.

In deciding the allowable limit of variation it is advisable, where it is possible, to take into consideration the natural changes that take place in a gauge from wear. For instance, suppose a piece of work .250 inch in diameter just fills the hole it is to go in, and a limit of .0015 inch is allowable; that is, if the piece is [illegible] make the [illegible] gauge for this work [illegible] there would be no allowance for wear of either the external or internal gauge.

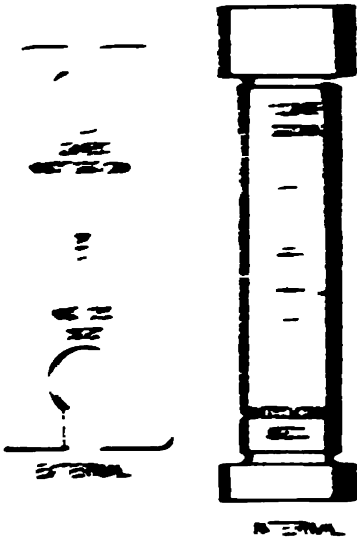

Fig. 316.

Fig. [illegible] gives an idea of one form of a snap gauge used for [illegible] measurements; however, it is not necessary to make [illegible] of the styles shown. The plug gauge may be made as shown in Fig. 317; while the snap gauge may be made as shown in Fig. 318. The same general instructions given for making plug gauges and snap gauges apply to limit gauges of the same character.

RECEIVING GAUGE.

[illegible] working points of a tool, [illegible] relation to one [illegible] gauge is used. This gauge as [illegible] take in the work; that [illegible] in the gauge, and the exact location of the different points [illegible] determined by the eye.

Fig. 319 [illegible] gun-hammer, while Fig. 320 represents a *receiving gauge for accurately* gauging the points C, D, E, F, G and H in relation to the fulcrum screw hole A and the face B. These points must also be in exact relation to each other; hence the necessity of a gauge of this character. When making a gauge of this type, it is customary in most shops to gauge only those parts that must be located in exact relation to some other point or points.

In the case of the gun hammer under consideration the fulcrum screw hole A must be the main working point because when it is operated it is pivoted at this point, consequently every point must be in exact relation to this hole. The point of next importance is the face B which strikes the firing pin; in order that the face of the hammer may be the proper distance from the firing pin when half cocked, or full cocked, it is necessary that the half cock notch D, and the full cock notch E be properly located as regards the face of the hammer. They must also be in exact location as regards the fulcrum-screw hole A. In-order that the main spring may exert the proper amount of force on the hammer, it is necessary that the spring seat G be exactly located. As the portions marked C and H are intended to just fill the opening in the gun frame when the hammer is in any position, it is necessary that they be located the proper distance from the center of the fulcrum-screw hole A; hence the need of a gauge that will determine the exact location of all points as related to A and B and to each other. As the por-

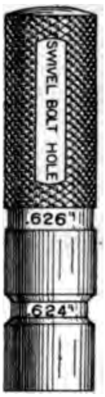

Fig. 317.

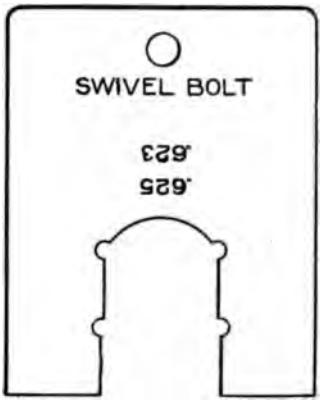

Fig. 318.

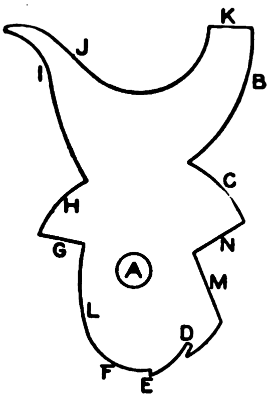

Fig. 319.

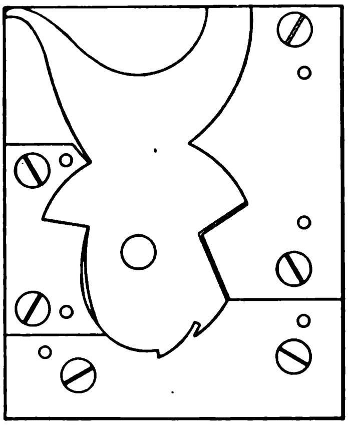

Fig. 320.

tions marked I, J, K, L, M, and N must be in *exact* location to the other points or to each other they are gauged with a *separate* gauge because each additional gauging point on a gauge of this description complicates matters.

When making gauges of this character a piece of machinery steel is usually taken for the base; this is planed to size and ground or filed for finish; a hole is drilled and reamed to receive a pin the size of the fulcrum screw hole. This pin is made of a piece of drill rod a few thousandths inch larger than the desired pin. The piece of drill rod should be long enough to be held in the chuck of the grinding machine, and should be cut of the proper length as shown in Fig. 321. The short end should be hardened and the temper drawn to a straw color; after which the wire may be placed in the chuck on the grinding machine and the pin ground to the desired size. After grinding to size it may be broken off and the end ground; this can be done by holding the pin in the chuck, leaving the broken end out in order that it may be ground square, the pin should now be forced to place in the hole in the base.

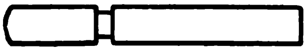

Fig. 321.

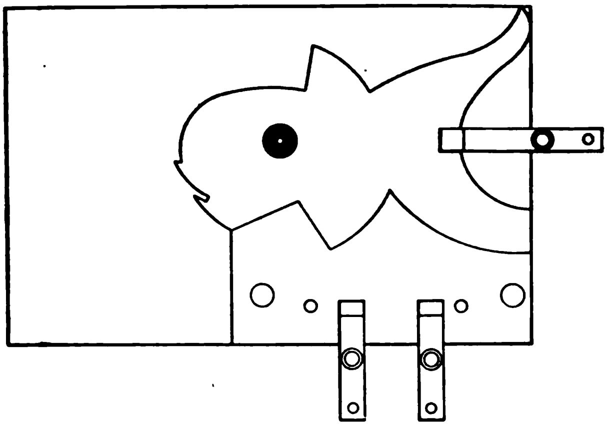

Fig. 322.

The gauge proper may be made of one plate worked to the proper shape, but better results will follow if it is made in three pieces as shown in Fig. 320 on account of the tendency of the plate to spring when hardened.

These plates may be made either of tool steel or machinery steel, if made of tool steel the pieces should be machined all over and thoroughly annealed, after which they may be planed or milled to thickness.

One surface should be colored by the blue vitriol solution, or the pieces may be heated until a distinct blue color appears; the desired shape should be marked on the colored surface and the pieces machined and filed until they fit the model, the necessary degree of accuracy must be determined by the nature of the work.

After the pieces are properly fitted to the model, they may be attached to the base by means of the fillister head cap screws shown. The model should be laid on the base having the fulcrum screw hole on the pin. After arranging the model in its proper location it may be clamped as shown in Fig. 322. The sections of the gauge which should have been previously drilled for the screw and dowel pins, may now be clamped to the base in their proper positions. After drilling, the holes in the base may be tapped, and the screws put in place. If it is found necessary to make slight alterations in any of the shapes, they may be readily made as the plates can be moved a trifle because the bodies of the screws need not fit tightly in the holes in the plates. The dowel pin holes should not be transferred into the base until after the plates are hardened.

The plates may now be removed and hardened. If of machinery steel they may be case-hardened, dipping them in oil rather than water. If made of tool steel best results will follow if the plates are pack-hardened, running them 1 to 1½ hours after red hot and then dipping in raw linseed oil.

If the process of pack-hardening cannot be used, satisfactory results may be obtained if they are carefully heated in a tube in an open fire, or placed in the muffler of a muffler furnace. When red hot, sprinkle a small quantity of finely powdered cyanide of potassium, or a little yellow prussiate of potash on the contact surfaces, place in the fire again, bring to a low red heat and plunge in a bath of oil.

After hardening, the plates may be attached to the base by means of the screws; if any of the gauging points have become distorted by hardening, they may be brought to the proper shape by oil-stoning.

When the plates are properly fitted and located in their exact positions, the dowel pin holes may be transferred into the base and the dowel pins put in place.

LOCATING GAUGE.

This form of gauge is used for determining the location of one or more holes in relation to another hole, a shoulder, or working surface, or any similar measurement.

Fig. 323 shows a gauge for showing the proper location of the hole from the edges A and B, Fig. 324. This gauge consists of a base having four pins for the edges A and B, to rest against. These pins are flatted on the contact edges to prevent wearing. The piece of work to be gauged is placed in position and clamped to the gauge with machinists clamps as shown in Fig. 325. The gauge is fastened to the face plate of the lathe in such a manner that the piece of work can be removed without disturbing the location of the gauge.

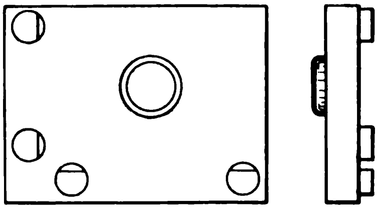

Fig. 323.

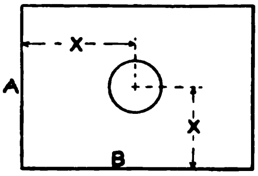

Fig. 324.

A short plug is now inserted in the hole in the model. It is necessary that the plug should fit very accurately. By means of a lathe indicator the gauge can be located so that the plug runs perfectly true. When this has been accomplished the model may be removed and the bushing hole drilled and bored to size; after which the bushing may be made, hardened, ground to size, and forced to place.

The location of the drilled hold may be tested by placing the piece of work on the gauge against the pins, and entering the gauge pin in the hole in the work and bushing, as shown in Fig. 326. If the pin is a close fit in the holes a very slight error in location may be detected. When a slight error in location is allowable, and it is not considered advisable to hold the location too close, the pin may be made a trifle small, thus transforming the gauge into a limit gauge.

When it is necessary to make a locating gauge for testing the center distance of two holes, one pin may be made removable, while the other is rigidly fixed as shown at C Fig. 327.

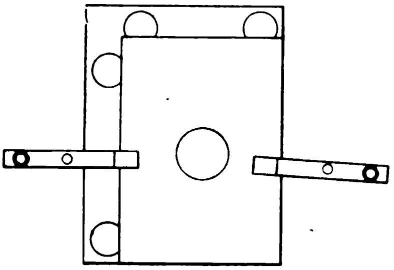

Fig. 325.

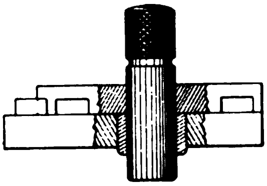

Fig. 326.

If the gauge is made with both pins fixed it is a difficult operation to remove the piece of work, provided the pins are a good fit in the holes. Withdrawing one pin allows the piece of work to be readily taken from the fixed pin.

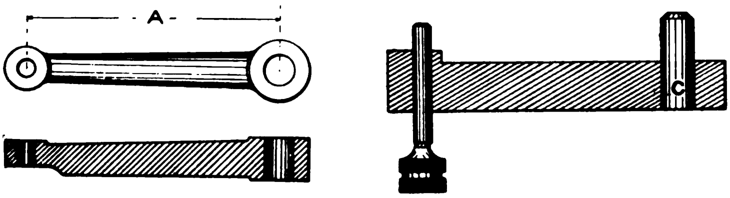

Fig. 327.

When making a gauge of the form shown in Fig. 327, the fixed pin C may be located by approximate measurements; but the hole should be drilled by some method that insures the pin standing perfectly square with the base of the gauge. If a small limit of variation is permissible in the center to center measurement A, the model may be placed on the gauge with the large hole on the fixed pin C, and the location of the hole for the movable pin may be transferred from the model by drilling and ream-

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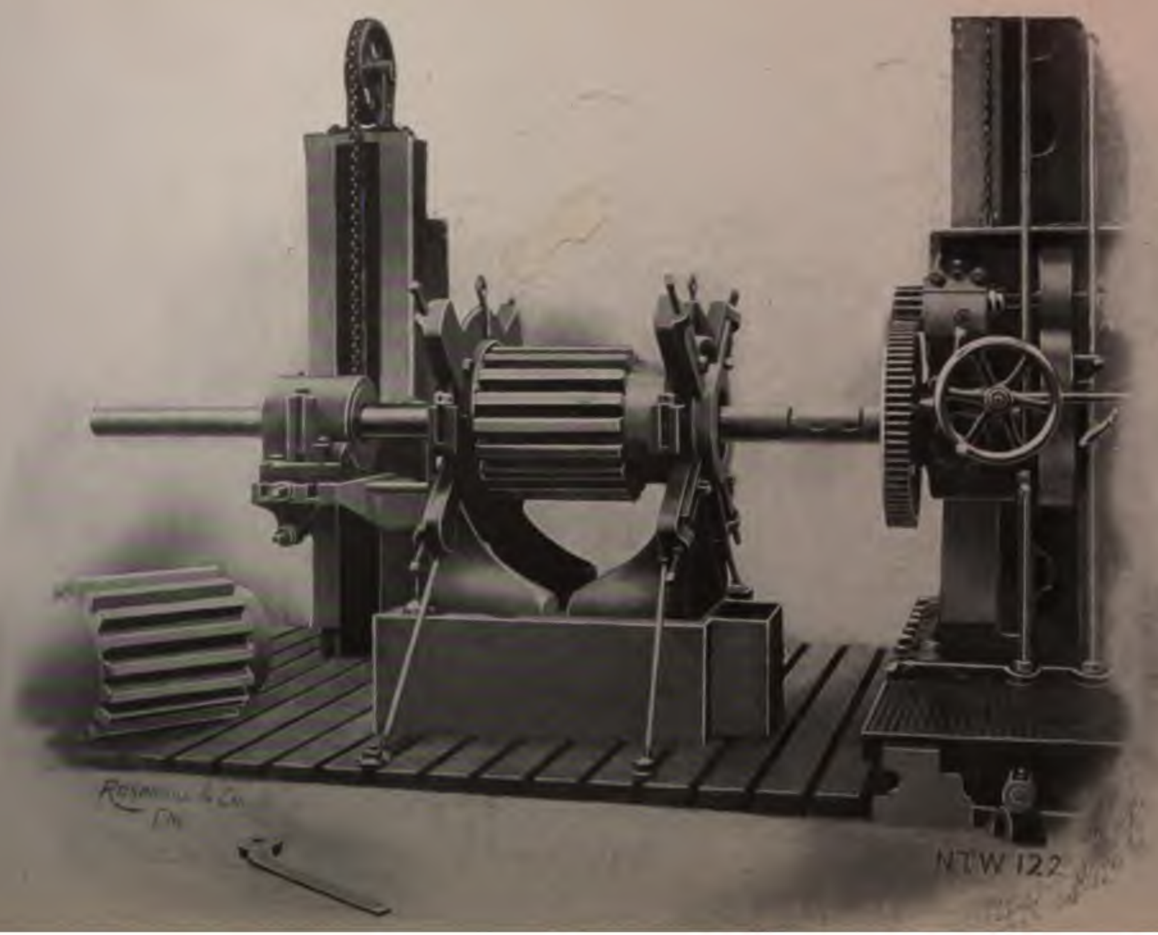

NTW 122

THE MANUFACTURE OF IRON

Out of the world's annual production of forty to fifty million tons of pig iron, the United States alone furnishes about eighteen million tons, or two-fifths of the entire output. Although the great bulk of this vast production is consumed in the United States, three to four hundred thousand tons are annually exported.

Over forty million dollars are annually paid in wages to the eighty thousand men and boys employed in the production of pig or cast iron. The yearly valuation of this product is over two hundred and fifty million dollars.

The ever-increasing consumptive power of the United States for iron and steel products has caused a phenomenal growth in this branch during the last twenty-five years. During this period it has risen from a little over one million to eighteen million tons. Of this tonnage Pennsylvania contributes about forty-seven per cent, while Ohio produces seventeen per cent, and Illinois about ten per cent. The growth of iron manufacture in these three states has been one of the most notable features in the industrial growth of the United States. The production of Pennsylvania alone to-day is seven times greater than the entire production of this country in 1870.

The Unloaders and Stock Pile of a Modern Dock.

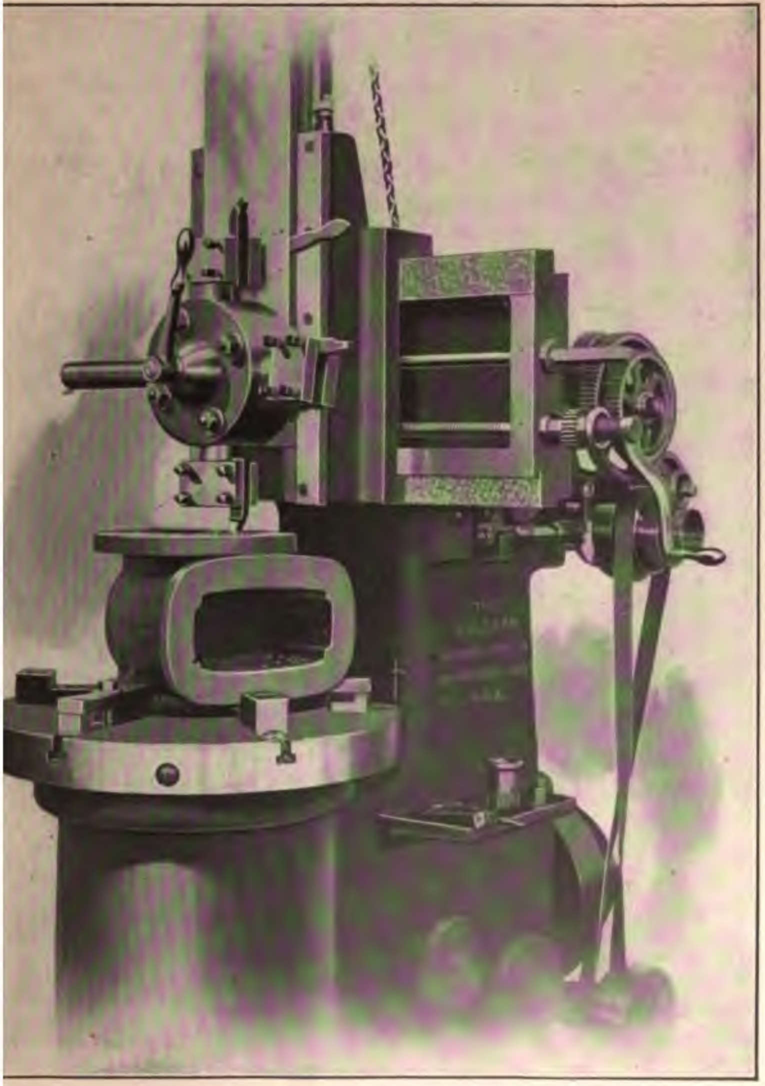
In 1870, when railroad construction was most active in this country, England, which produced three times as much iron as did this country, furnished us with all of our rails and other material. After that, Germany took the lead, but only to be surpassed by the United States, which to-day has an output almost equal to that of England, Germany and France combined.

The great and rapid advancement of the United States in this branch of industry is due, to a great extent, to its rich, reliable and easily obtained iron ore and its unsurpassed coking coal, the two forming the most essential ingredients used in iron making. These, aided by the modern and inexpensive handling and by splendid transportation facilities, reduce the cost of manufacture to such a low figure that American iron can be transported and sold in foreign countries at a large profit.

Unloading a Vessel.
The modern method of unloading the huge ore-carriers at the rate of six to seven thousand tons every ten hours.

The channels of consumption of this enormous tonnage are numerous and extensive, affecting almost every walk of life. Five million tons is of grades suitable for foundries, for the production of iron castings for machinery, railroad rolling stock, cast-iron pipes, and a variety of small uses. About half a million tons is converted into wrought iron, while another half million is used for steel castings. The remainder, amounting to about eleven million tons, is utilized as the basis of steel manufacture.

The actual manufacture of iron dates back almost to the prehistoric era, but it was not until 1620 that it was introduced into



BORING AND TURNING MILL.

Finishing Seat and Facing Flange of Valve.

Bullard Machine Tool Co.

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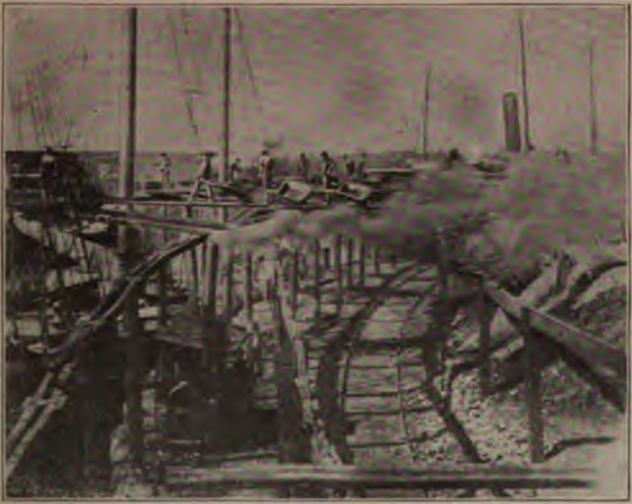
the United States. From that time on the improvements were rapid and wonderful, the foremost of which were the introduction of coke in the eighteenth century, the steam engine in 1769, and the hot blast of J. B. Neilson in 1828.

A splendid example of one of these antiquated furnaces can still be seen near Lakeville, Conn. It was built in 1762; and so excellent was its product that cannon, cannon balls, shells, etc., were used therefrom, as also the large chains which were stretched across the mouth of the Hudson during that exciting period.

Pig or cast iron is not pure iron, but an alloy of which iron is the most important ingredient. Unlike many of the common alloys, such as bell metal or brass, which are composed of a mechanical mixture, it consists of a large, complex union of many and different elements, such as carbon, manganese, silicon, sulphur, phosphorus, etc. The most important of these is carbon, which gives fluidity to the metal when molten and hardness when cold.



Old Method of Unloading Ore Vessels.

The three principal ingredients used in its manufacture are iron ore, coke and limestone. In a few cases, charcoal, anthracite, and bituminous coal are used, alone or mixed, in place of the coke. All of these are plentiful in this country and of most excellent quality.

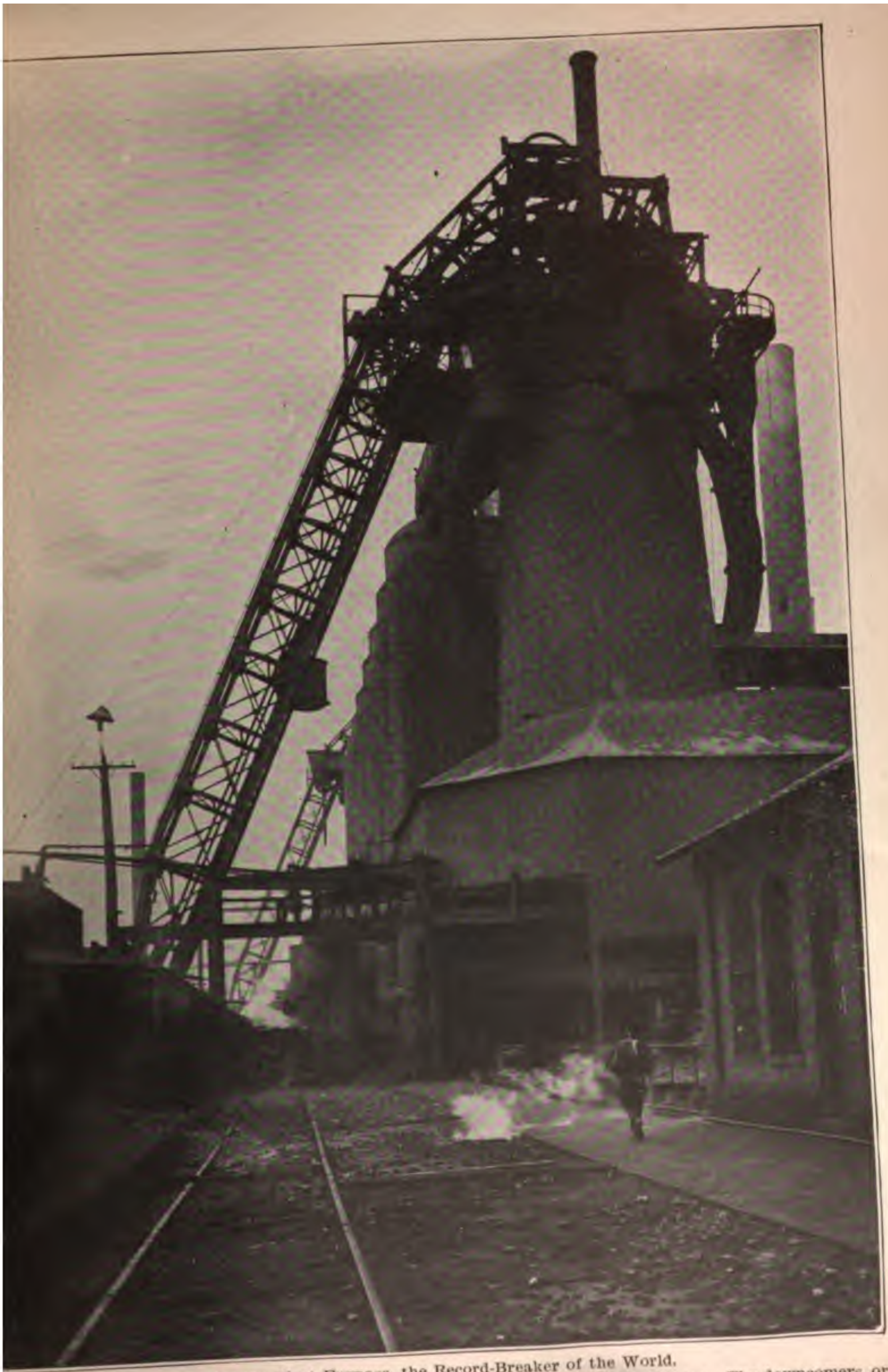
The iron ores of this country are divided into four general classes, the high-grade ores containing about fifty to sixty per cent of iron, and the low ores, thirty to fifty.

Although small quantities of ore are found in Alabama, New York, Pennsylvania, New Jersey, Wisconsin, Minnesota, Michigan, Virginia, and West Virginia, about eighty per cent of the total is mined in the famous Lake Superior region, of which the following are the principal ranges: The Masaba in Minnesota, the Menominee in Michigan and Wisconsin, the Marquette in Northern Michigan, the Gogebic in Michigan and Wisconsin, and the Vermillion in Minnesota.

The iron ore in the United States may be considered in four general commercial classes—red and brown hematite, magnetite, and carbonate. Of these four, the red hematite is the most popular, because of its richness in iron and its freedom from foreign and non-metallic material. These classes are subdivided under various local or trade names.

A Steam Shovel "Bucking" a Bank of Ore.

Three general methods are employed in the United States in mining the ore—surface, drift, and underground. In locations where the ore is very hard or lies at a depth of sixty feet or more from the surface, the latter method is employed. Shafts or tun-



Modern Blast Furnace, the Record-Breaker of the World.

he cut shows the skipway, up which the material is carried to the top of the furnace. The downcomers, or pipes down which the gas travels, are also very plainly illustrated.

nels are driven to the ore beds, which are then worked in a similar manner to coal. In those districts where the ore is found in a loose condition just under the surface, surface mining is almost altogether followed.

Surface Mining. Where surface mining is employed, the ore must be easy to get at. The top soil is first removed by steam shovels, after which the ore can readily be taken out in the same manner. The mine being thus opened or "stripped," tracks are laid in all directions upon the face of the deposit. These excavations are usually worked in terraces. The ore, being lifted by the numerous steam shovels, is placed directly on specially constructed cars, in which it is hauled to the docks. In this manner immense quantities of ore are obtained at a cost not exceeding forty cents a ton, while the drift and underground require an expenditure of seventy to eighty cents a ton.

A Stream of Molten Iron Running into the Sand Moulds, Forming the Rough Bars. which, when Solidified, are Termed "Pigs."

The ore ranges of Lake Superior have added more to the economical advancement of American iron than any other single thing. They have given birth to the thousands of miles of railroads that are scattered throughout that district and that devote their entire traffic to the transportation of iron ore. They have added to the Great Lake shipments millions and millions of tons; given employment to thousands of boat builders and crews; forced the Government to make improvements throughout their course; and caused the growth of towns all through the mining districts and the building of the largest docks in the world.

Docks. With typical American enterprise these docks are built with the latest labor-saving devices. The specially constructed cars are run out upon them, and their hopper floors dropped, permitting the ore to fall into numerous bins below. Underneath and on both sides are long rows of chutes through which the ore passes into the holds of the large ore-carriers. These boats are invariably filled to their very hatches. Over twenty-one million tons of ore were transferred through these docks last year. The magnitude of these structures can therefore readily be imagined. In winter all shipments are suspended; consequently a large accumulation of ore must always be stored in the East, either at the docks or at the furnaces. Some vessels have a tonnage of six thousand tons, and so perfect are the loading facilities that it seldom requires over five hours to load them. After a trip through Lakes Superior, Michigan, Huron, and Erie, the immense ore vessels arrive at one of the unloading docks of Cleveland, Conneaut, or Ashtabula.

An Old-Time Blast Furnace.
One of the first furnaces in this country, still standing near Lakeville, Conn.

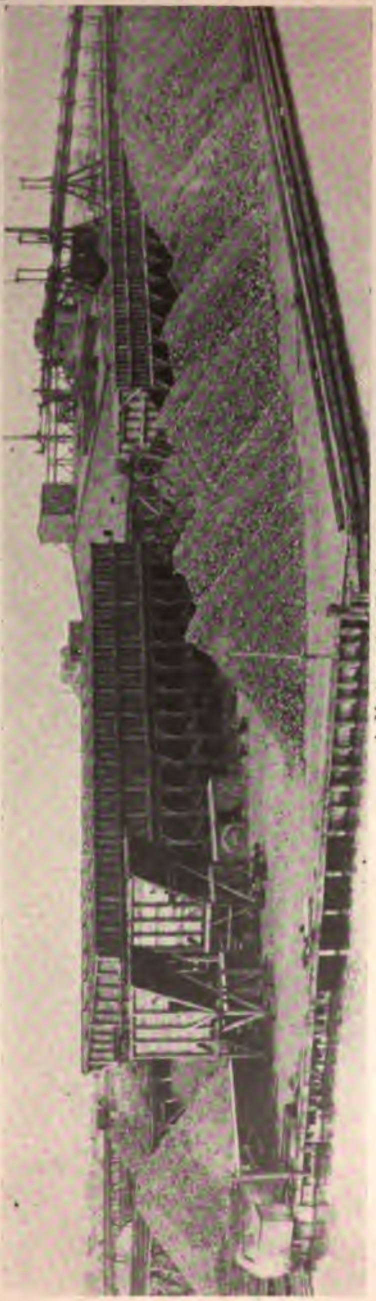
Here on every side are the huge yet rapid machines that transfer the ore from the ship's hold to the huge pile on the docks. These machines have grown to such perfection and magnitude that

the ore boats are rarely held longer than ten hours to have their contents transferred to the storage piles.

As wanted, the ore is loaded into cars, either directly from the steamers or from the stock piles, and transferred by rail to the furnaces. The great Pittsburg district is the destination of the greater portion of this ore. So thoroughly mechanical and free from labor have been these numerous operations of mining, loading, transporting, and delivering the ore in the Pittsburg district, that an expenditure of only two dollars and fifty cents a ton has been incurred.

The greatest advancement which American iron manufacture has made in recent years is in the handling of the raw and finished materials at the furnaces. This is due largely to the great increase of tonnage during the past ten years. Over ninety million tons of raw and seventeen million tons of finished material were handled in 1905 at the four hundred and twenty-eight furnaces scattered throughout the United States. The raw material alone represents an expenditure of over one hundred and thirty million dollars.

In contrast with the old-



A Modern Ore Dock.

fashioned method of hand labor, mighty machines are to-day employed. From the moment the long trains of ore, coke, and limestone arrive, through the period of unloading, charging, melting, casting, and loading the finished iron, man never once enters into the operation. The ore cars are lifted upside down and their contents dumped into large iron buckets, which automatically carry them either to the long row of bins or to the large stock piles. The cars containing the coke and limestone are run upon a trestle under which are arranged the bins. By this method they can deliver their contents directly into the bins without any additional handling, the cars being provided with bottom gates. Many of the largest plants have sufficient bin space to permit a large quantity of ore to be similarly stocked, thus reducing the cost and holding the large stock supply for emergency and winter usage.

THE BLAST FURNACE

The modern blast furnace is a gigantic structure, oval in shape and some ninety to one hundred feet in height. It consists of an outer coating of steel plates, with an inner lining of fire brick. Accompanying these stacks are invariably two or more cylindrical steel structures known as stoves. They are usually smaller in diameter but as high as the stacks themselves. Their particular work consists in utilizing the waste gases to heat the blast for the furnace.

The Casting Machine.
The modern method of solidifying the iron.

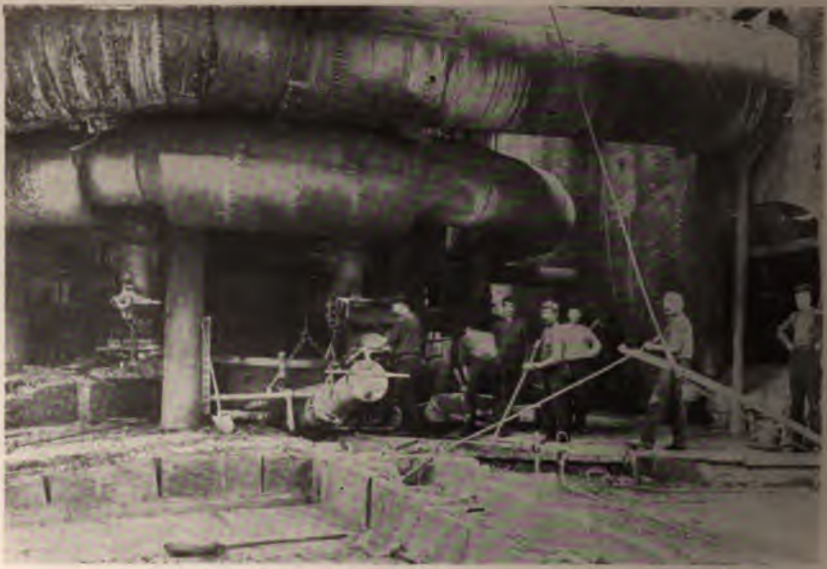
Charging. Running parallel to the long row of furnaces are the immense steel bins or trestles filled with the ore, coke and limestone. At the bottom of this structure are small electric cars which are kept busy, transferring the desired ingredients—ore, coke, and limestone—from the pockets at the bottom of the bins to the skip car. This being done, the skip, which operates upon an inclined track from the ground to the top of the furnace, is conveyed to the top, where it automatically empties its charge into the upper or receiving bell. When filled, the bottom of this bell is lowered and the material allowed to fall into a second and larger receiver. When this has received its full quota, consisting of several such loads and known as a "charge," its bottom is lowered and the charge distributed uniformly in the furnace over the top of the previous charge. By these two bells or bottoms, the top of the furnace is at all times closed. The furnace is usually kept filled within a few feet of its top.

Running the Molten Iron into Ladles.

But this is only a portion of the operation. Encircling the lower outside portion of this tremendous test tube, so to speak, is a large pipe punctured at regular intervals by smaller ones which terminate in the interior of the furnace. The powerful air-blast goes rushing through these pipes into the body of this mass, where every atom of it is caught and utilized in some form or shape for the complicated reaction therein.

There are two distinctive series of operations in the blast furnace—those which accompany the charged materials on their downward journey, and those of the ascending gases.

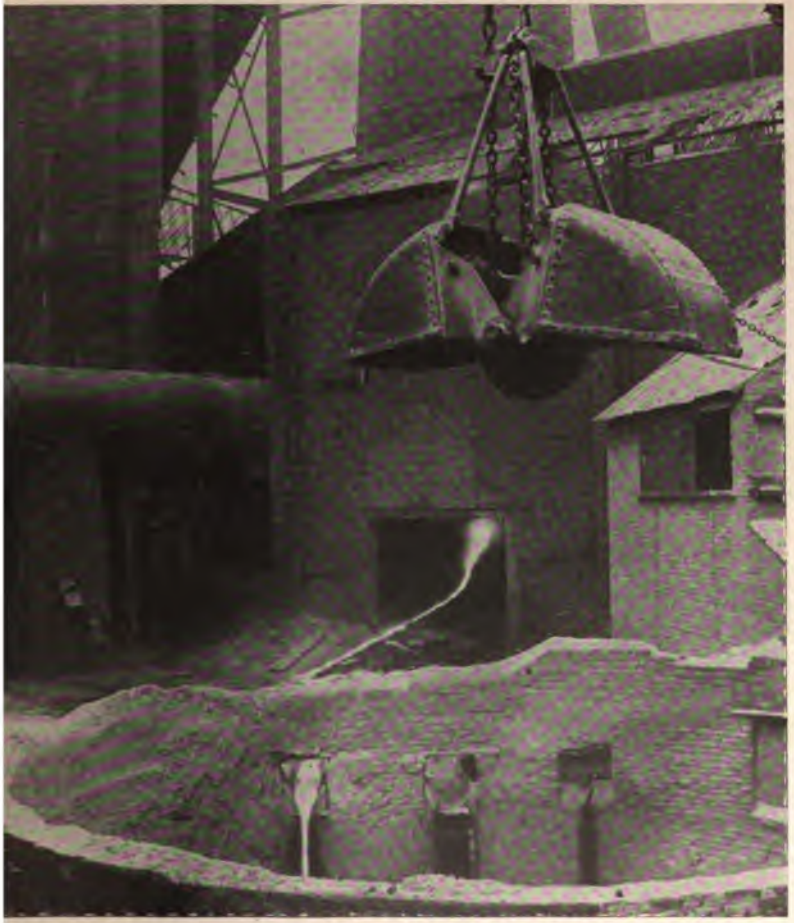
As before stated, the superheated air-blast enters the lower portion of the furnace from all sides at a pressure of about sixteen pounds to the square inch. Immediately upon its contact, the coke or coal, whichever is used as fuel, becomes combustible, the oxygen of the blast uniting with the carbon of the fuel, forming the gas CO_2 and a most intense heat. This gas ascends, and during its contact is reduced to CO. Upon its contact with the highly heated ore and limestone, the CO reduces the ore, the other gases assisting by heating the materials in the upper portion of the furnace. The limestone is first changed into caustic lime, which unites with the alumina and silica of the ore and ash of the fuel, with the result of a double silicate of lime and alumina. This is very fusible and does not mix with the iron.



Closing the Iron Notch after Running a Blast from the Furnace.
The large pipe circling the furnace is the bustle pipe, through which the hot blast is carried to the furnace.

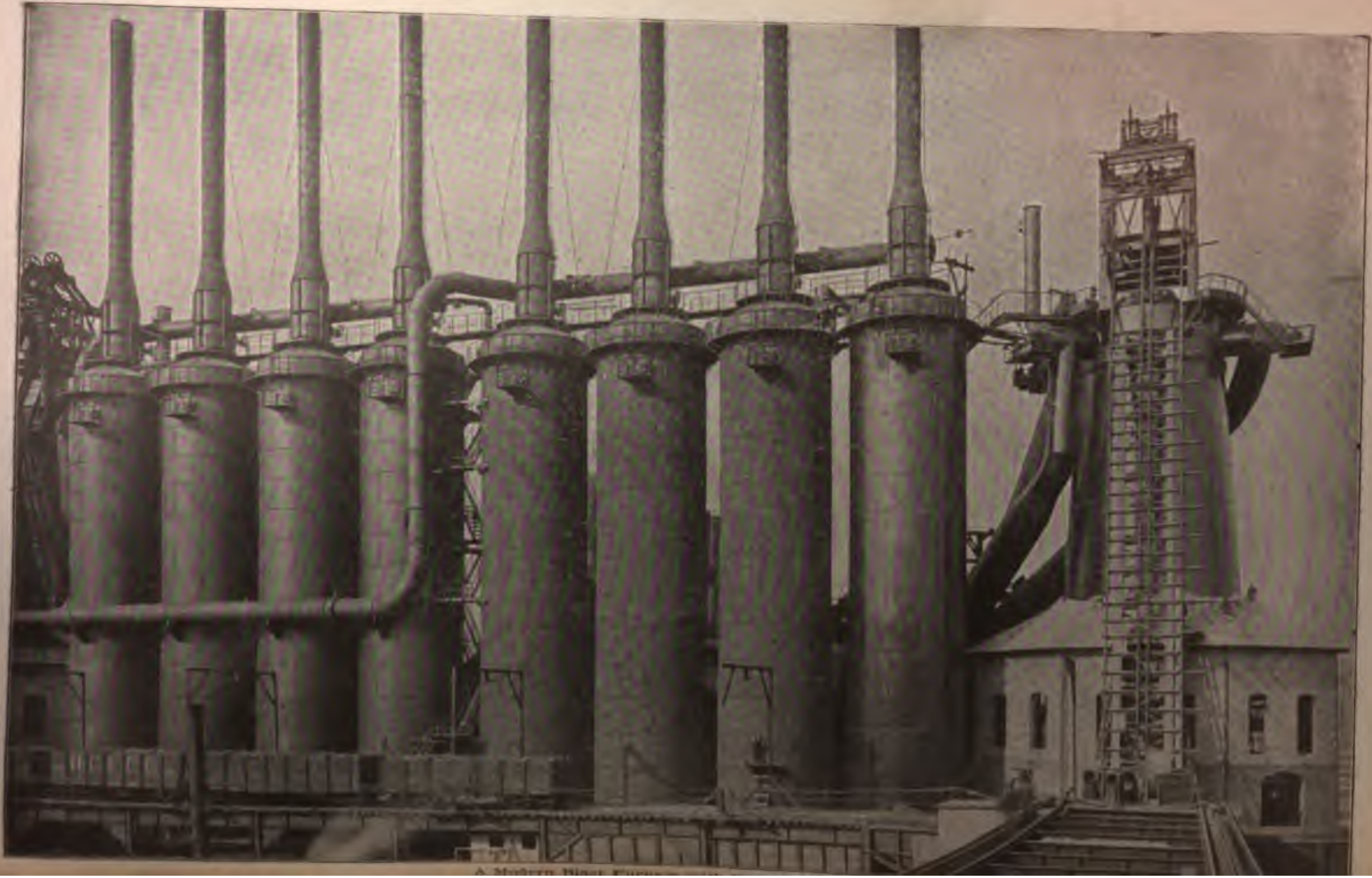
The incombustible and solid matters are so mixed and pro- tioned with the combustible and fusible materials that the en- charge, when heated, will result in only fusible matter.

The slags, caused from the earthy matters of the ore mixing h the fluxes, follow the iron on its downward course. This, turn, drips or falls into a large brick-lined receptacle in the ttom of the furnace. Owing to their lower specific gravity, the gs float on top of the iron, protecting the same from the in- ence of the blast.

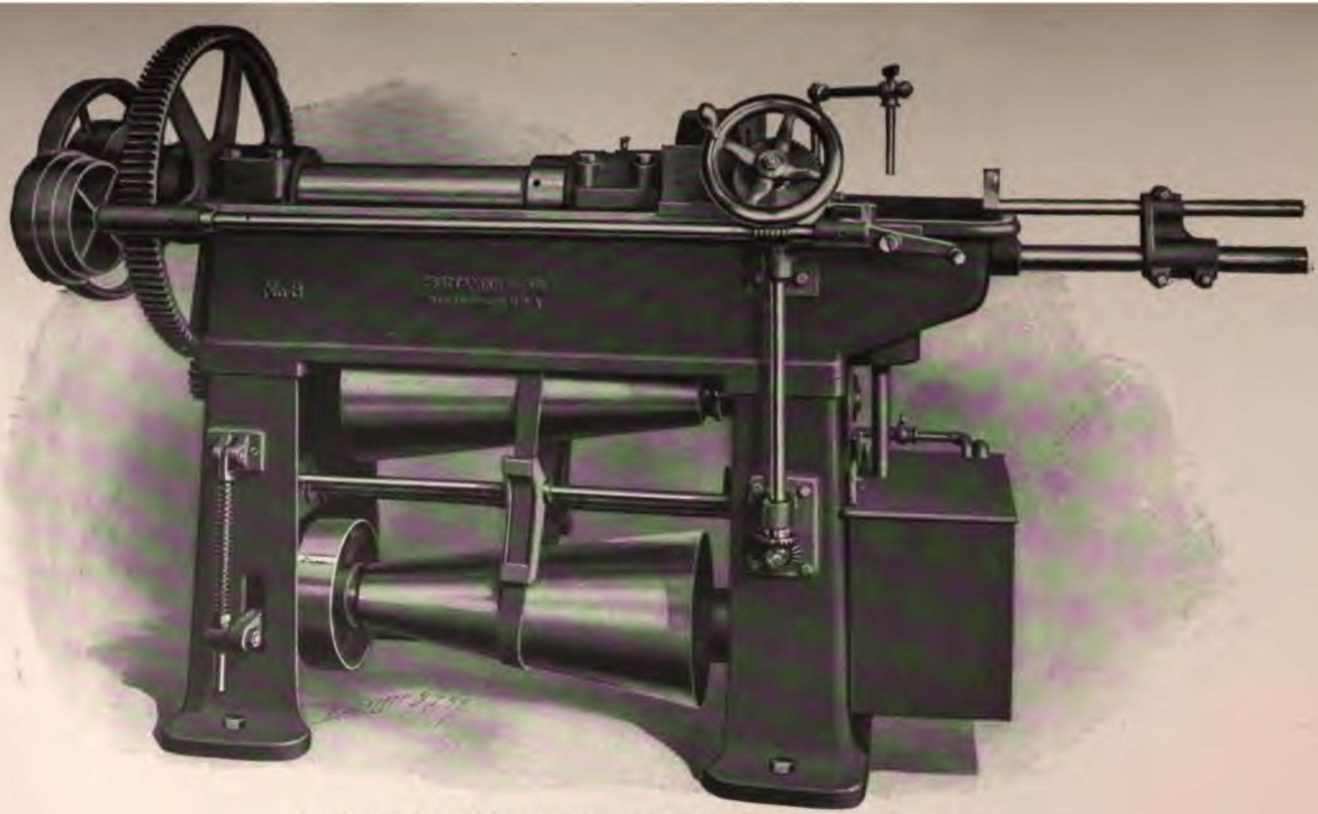


Running the Hot Slag from the Furnace into the Cinder or Granulating Pit.

Utilizing the Gases. The gases accumulating from this con-



A Modern Blast Furnace



CUTTING-OFF MACHINE WITH INCREASED SPEED MECHANISM.
Pratt and Whitney Co.

THE NEW YORK
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ASTOR, LENOX AND
TILDEN FOUNDATIONS

glomerate mass of liquid, semi-liquid, and heated substance, rise to the top. Not finding an escape through the charging bells, they dart down the two or more "downcomers" which are provided for this purpose. Here they are led through a box, where the cinders and other solid matters are extracted. A portion of the gases is now carried through pipes to feed the boilers, while another portion is utilized in the heating of the stoves.

These stoves, as before mentioned, are large, cylindrical structures whose interiors are masses of fire brick. These bricks are so arranged as to allow the greatest amount of surface to be exposed. In this manner they are thoroughly heated. Each furnace has a set of such stoves, some of which are always being heated, while others are giving their heat to the blast which is driven through them prior to entering the blast furnace proper. At intervals these stoves are changed, the cold ones heated and the hot ones employed for heating. This method of utilizing the waste gases is a comparatively new invention, but one which has almost revolutionized the iron industry.

Casting. Formerly there was but one method of casting pig iron; but, because of the rapid advance in the uses to which this material is adapted, several methods are now employed. The ultimate results of these methods are of a physical rather than a chemical nature. In any case, however, the iron is first tapped through an opening near the bottom of the furnace, at periods of four hours' duration. Leading from this is a long channel in the sand, through which flows the white, glittering iron.

If it is to be cast in the form of sand pig, the metal runs into a long channel in the sand, with smaller ones running at right angles to both sides. These are called "sows." Flowing from the sows, the iron is fed into smaller moulds, about three feet long and four inches wide. When solidified, these "pigs," as they are termed, are broken from the sows and loaded into cars, ready for shipment. Iron thus cast has an accumulation of adhesive sand upon its surface. It is not extensively used in any processes where sand or silica is a detriment.

When wanted for basic purposes and free from sand, another method is employed. Instead of permitting the iron to run into the sand moulds, it is run through the channels into specially constructed ladles or vessels which operate upon wheels. These have a capacity of 18,000 pounds each; five to six are usually filled from each blast or cast. As filled, they are drawn to the casting house, where they are tilted in such manner as to permit the molten metal to run into an endless chain of cups. These cups are about two feet long and eight inches wide at the base, and are attached to an endless chain that rests upon a track. By means of an engine or motor, the chain is revolved, the cups passing through a long tank of water, at the end of which is an incline, up which the chain bearing the cups passes. When it reaches an elevation of about ten feet, the chain passes over two gear wheels on its way back. The cups turn up-side-down, throwing their now solid contents into a car beneath.

Filling the Skip Car with the Necessary Material to Make a Charge.

During recent years the expense of casting has been greatly lessened by the invention or practice of using the iron direct in its molten condition. It is transferred in ladles direct from the blast furnace to the steel furnaces, thus avoiding a second melting in the latter operation.

The slag is run off at irregular intervals, in a manner similar to the iron, but through an opening above the iron line. This avoids any possible waste of iron. Channels are built in the sand to lead the slag from the furnaces to either a granulating pit or to the ladles. In the former case it falls into a large pit or well containing water. The hot, liquid slag, coming in contact with the water, solidifies in the form of shot or sand. This is continually being lifted out by large electric scoops and loaded into cars. In this form it is utilized either for cement or ballast. If ladles are used, the molten slag is allowed to flow into several specially built ladles, which, when filled, are carried away and dumped into ravines and hollows.

There are many grades of iron, different only as to their chemical composition. The most common of these are: Foundry, gray forge, mottled, white, standard Bessemer, basic and malleable Bessemer. The foundry irons are subdivided into Nos. 1, 2 and 3, according to the percentage of silicon.

ANALYSIS OF PIG IRONS

The following table gives a rough analysis of the several grades of pig iron:

GRADE	SILICON	SULPHUR	PHOSPHORUS	MANGANESE
No. 1 Foundry......	2.50% to 3.00%	.03% and under	.40% to .80%	.30% to .60%
No. 2 Foundry......	2.00% to 2.50%	.04% and under	.40% to .80%	.30% to .60%
No. 3 Foundry......	1.75% to 2.25%	.05% and under	.40% to .80%	.30% to .60%
Gray Forge........	1.25% to 1.75%	.07% and under	.40% to .90%	variable
Mottled.............	about 1.00%	.10% and under	variable	variable
White..............	about 1.00%	.15% and under	variable	....
Standard Bessemer	1.00% to 2.00%	.05% and under	.10% to .20%	....
Basic...............	1.00% and under	.05% and under	.50% to 1.00%	....
Malleable Bessemer	1.25% and under	.05% and under	.05% and under	....

THE MANUFACTURE OF STEEL

This is the age of steel. From the delicate embroidery needle to the one hundred-ton gun, the most important tools of civilization are made of steel. The steel industry is the index to the prosperity of the whole people; it marks also the place of a nation among its peers.

The United States makes more than one-third of the world's production of steel—fifteen millions out of a total of thirty-six and one-half millions of tons; it is the richest and most prosperous among the nations. The two statements are complementary. Germany comes second, with an annual production of 8,000,000 tons; and England third, with 5,000,000 tons. The 450 steel works scattered throughout the United States represent a total investment of over $442,000,000, and pay $103,000,000 annually in wages. These figures cover only the actual production of steel in its crude form, a process in which man has rapidly been superseded by the marvelous and all but human machines. The magnitude of the industry in its entirety, representing a capital of billions and employing millions of wage-earners, may therefore be imagined.

Definition of Steel. Steel is so closely allied, in certain particulars, to cast and wrought iron, that a complete and satisfactory definition of it is almost impossible. Though differing considerably in their physical and chemical properties, they are all alloys of iron and carbon, the essential difference among them being in the percentage of carbon. Wrought iron usually contains less than 0.30 per cent of carbon, and is not materially susceptible to hardening when suddenly cooled. It invariably contains slag and is malleable. It is the product of the "puddling" furnace.

Steel usually contains between 0.08 and 2.00 per cent of carbon. Although its minimum limit extends within the bounds of wrought iron, it is free from slag. With but few exceptions, steel is capable of hardening and is malleable at some temperature.

Cast or pig iron contains, as a rule, between 2.00 and 4.00 per cent of carbon, but is not malleable at any temperature. From these definitions, therefore, it is seen that steel is the alloy between cast and wrought iron.

Processes Used. To obtain the physical and chemical properties needed for the numerous and almost totally different uses to which steel is put, several processes are employed in the conversion of the iron scrap and other raw materials into steel. The most important of these are the "Bessemer," the "open hearth" and the "crucible" processes. The first of these, named after the great inventor, Sir Henry Bessemer, is the method by which the majority of cheaper steels are manufactured. Accordingly, we find the great tonnage of rails, structural shapes, shafting, and the lower grades of sheets and wire, produced in this way. The open hearth process furnishes the steel for springs, shovels, the better grades of wire, forgings, plates and other articles, in which a higher grade of material than Bessemer is required, yet a grade not so fine as Crucible. When the highest grade of product is desired—such as edge and cutting tools, surgical instruments, razors, saws, die blocks etc.—steel from the crucible furnace is utilized.

Crucible Process. Crucible steel is made in much smaller quantities than the other forms of steel, the endeavor being to obtain quality rather than quantity. Consequently it is a very high-priced steel, the finer grades selling as high as sixty to eighty cents a pound.

The mixture for melting, consisting of definite and carefully weighed amounts of certain grades of wrought iron, blister bar, alloys and scrap, according to the grade of steel desired, is packed in pots varying in capacity from 50 to 150 pounds. These pots are usually composed of plumbago and German clay, although in England a clay pot is almost altogether used. The life of the plumbago pot varies according to the manner of treatment, the mixture of materials melted within it, and the quality of the pot itself; but on a rough average it might be stated that each can be used three times. The pots being filled, and a cap placed upon each, they are lifted one by one and placed in the furnace.

Although the crucible process is one of the oldest, but little advance has been made in its operation. The furnaces of to-day and the methods employed, are practically the same as those in vogue during the times of our forefathers in 1789.

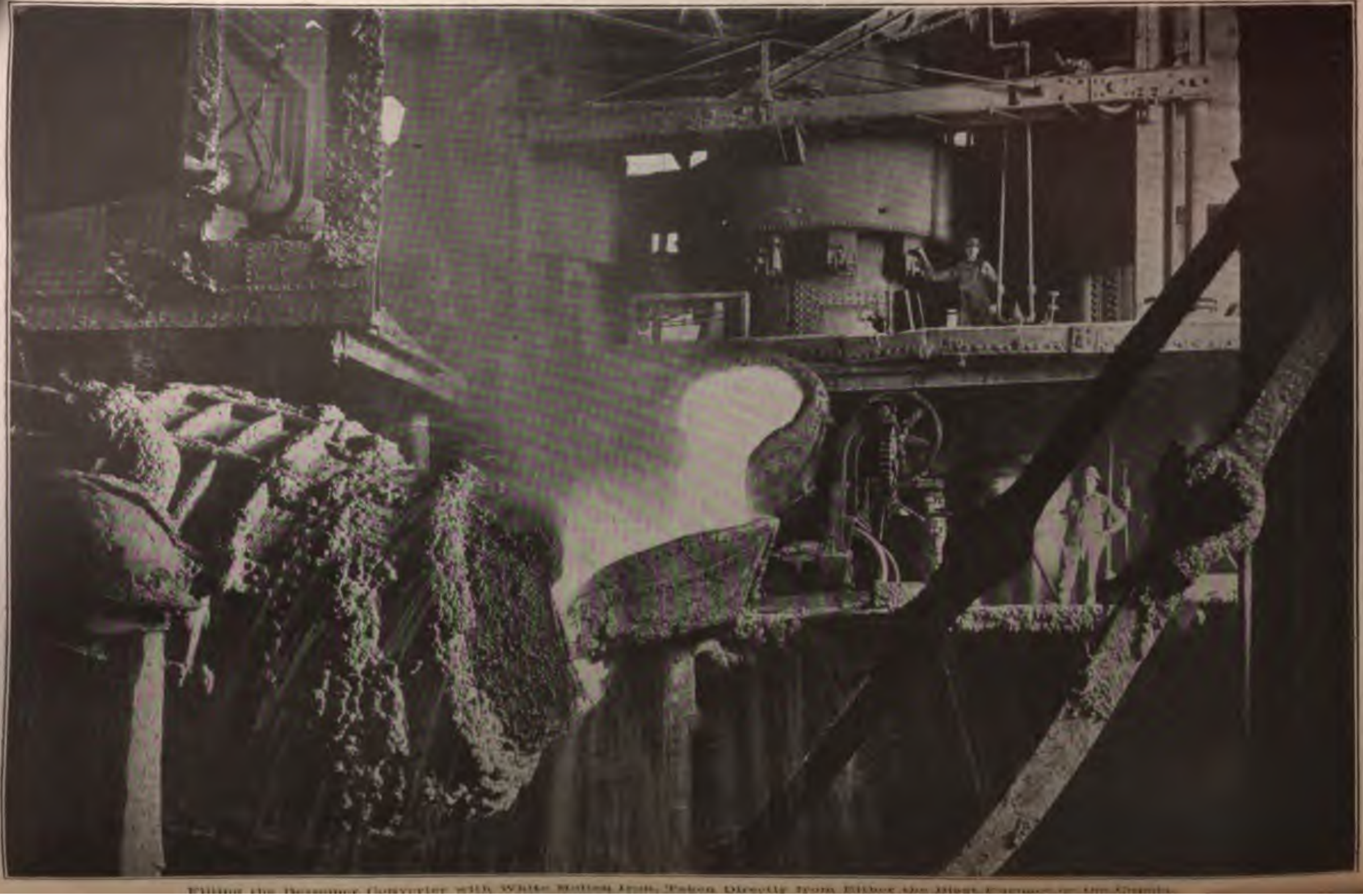
The furnace proper consists of numerous holes, varying in number according to the size of the furnace. In America the furnaces usually contain from four to ten holes, six pots being placed in each, three abreast and two deep. The pots rest upon a thick layer of coke dust, which is able to withstand a very severe heat without becoming spongy or liquid, the coke dust making a very firm yet easy rest for the pots. Each hole is provided with three covers, which are easily removed by means of a lever.

The furnace being thus charged, and the covers placed over the holes as closely as possible, the gas and air are permitted to enter. Rushing through the superheated chambers on one side of the row of holes, they meet and pass through the flues into the furnace.

Molten Iron Being Poured from the Mixer into Ladies.

It is in this vessel or furnace that the iron is mixed uniformly, previous to being used in the open hearth steel furnaces.

Circulating around the pots, this heated gas, which rises in temperature to about 3,000° F., finally passes through the opposite flues into the chambers on the opposite side. Passing through



Filling the Bessemer Converter with White Molten Iron, Taken Directly from Either the Blast Furnaces or the Cupola.

these and thoroughly heating the same, it finally passes up the stack.

The pots are subjected to this terrific heat for two and a half to three hours, when the melter, by means of an iron rod, pushes the caps of the pots aside to ascertain whether the mass is melted. When melted it is still left in the furnace, in order to boil out any gas which might be held in solution. This is termed "killing" or "dead melting." Having been "killed," the molten steel is ready to be cast.

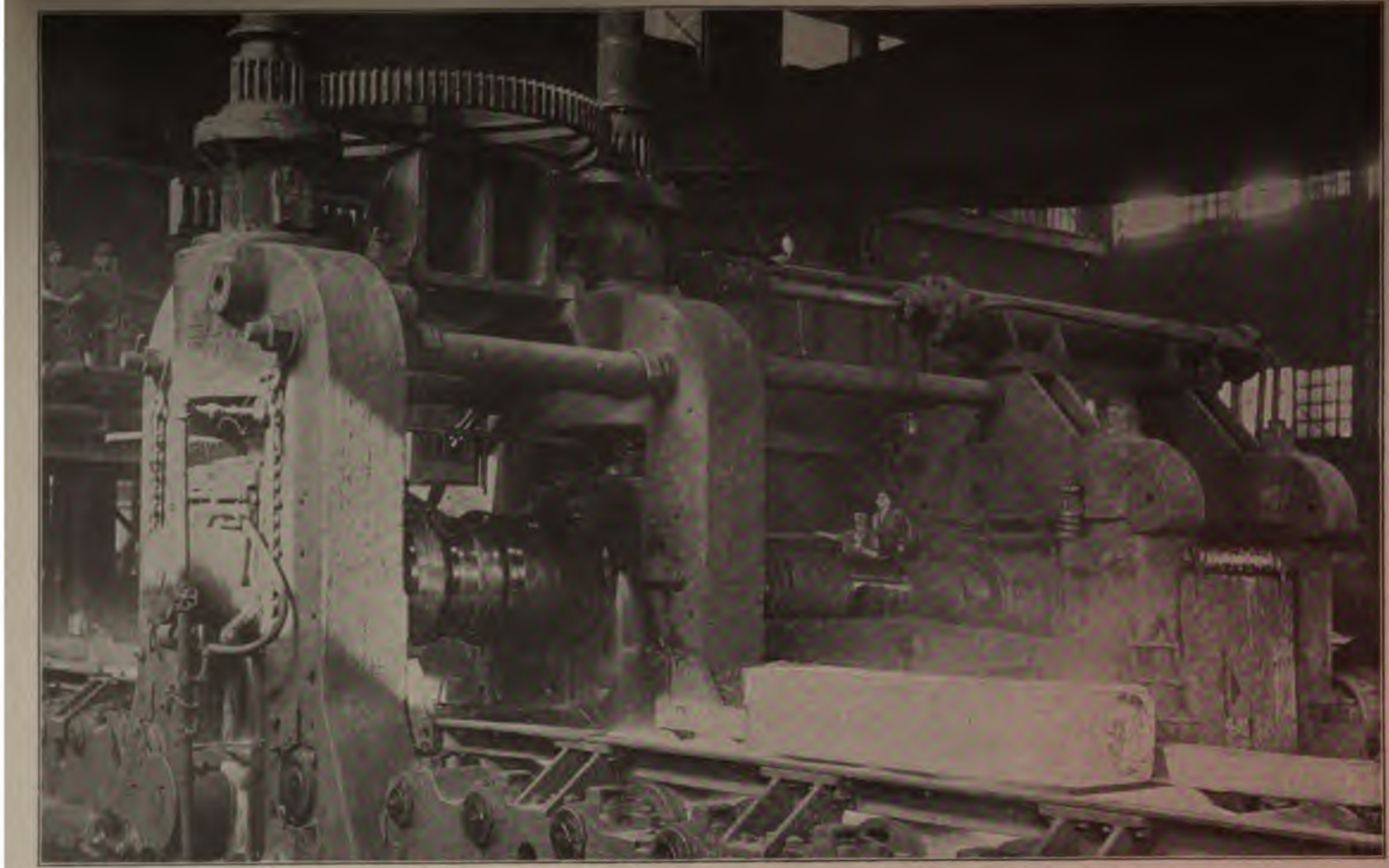
In preparation for this work of casting, the men wrap their legs with carpets, rubber, etc., and soak themselves with water. The cover is drawn from one of the holes; and the "puller out," dressed as above described, stands over the furnace or hole, and by means of a pair of tongs pulls the pots out, one at a time, carrying them to the moulds, which are standing in the casting pit at the end of the floor. There the molten steel is poured into the moulds, which stand upright. As a rule, the moulds are of one-pot capacity, but, if larger ingots are desired, larger moulds are employed, the metal being obtained from several pots. Care is taken that the stream from the two pots is not broken, the liquid flowing continually. If this is not done the result will be a defective ingot.

The pots, if in good condition, are refilled, and placed back in the furnace. When the steel in the moulds has solidified, the moulds are unfastened and the hot ingots drawn out, ready for another department.

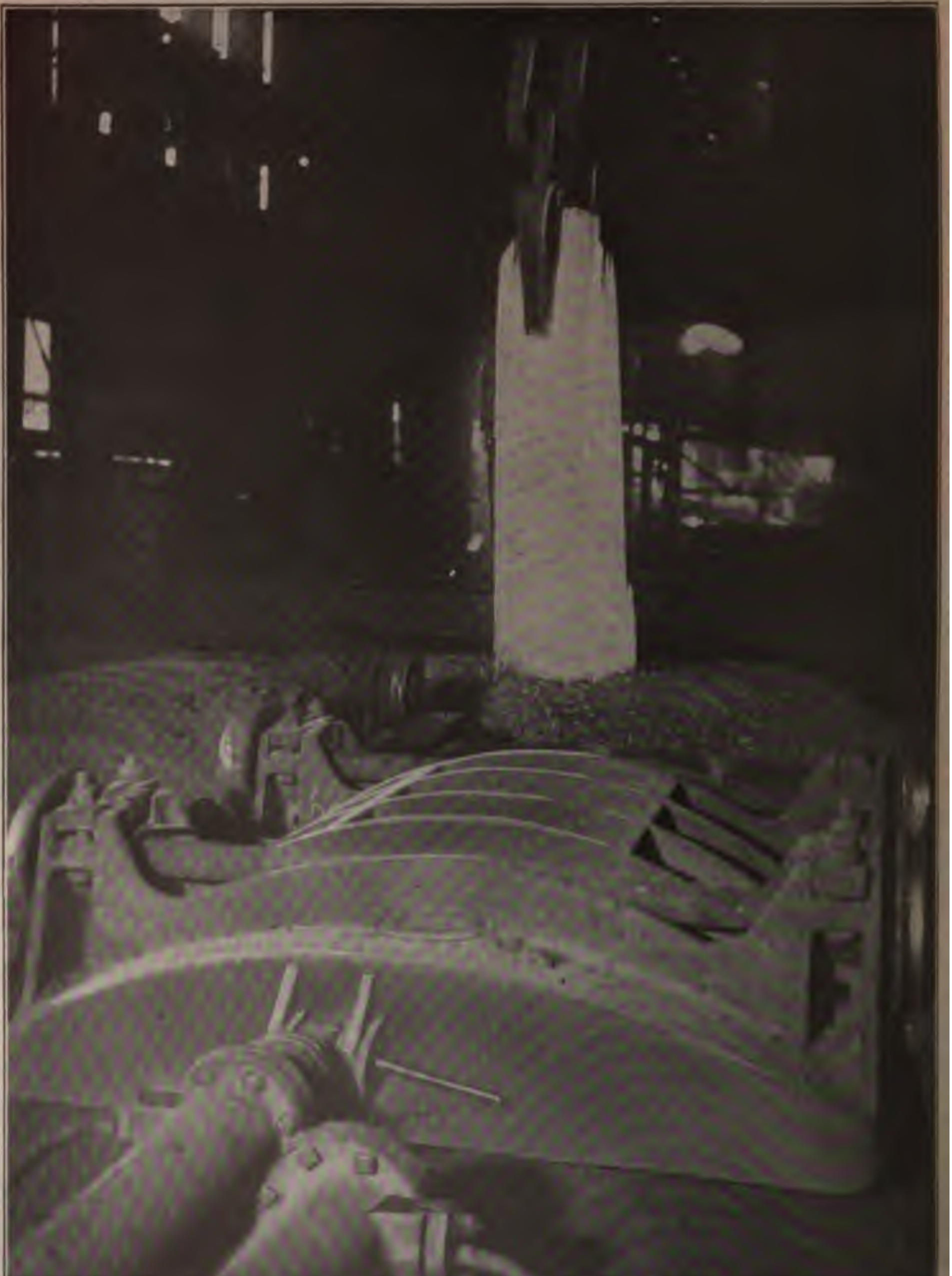
The ingots are first taken from the casting pit or furnace to the "tempering" department. Here, by means of a sledge, the top of the piped end of each ingot is knocked off in order to expose the grain of the steel, thus permitting an experienced eye to ascertain the carbon percentage of the same. In mild ingots, and those of a shape or size that will not permit of the ends being removed, a small corner of the ingot is chipped off.

The formula being marked upon the ingot, indicating the grade and the percentage of carbon, the ingot is then either piled in stock or taken directly to another department. Unlike the products of other processes, many grades of crucible steel are first welded—hammered at a high heat—thus refining the grain and destroying many of the blow holes or gas holes. The steel is then

Casting the Molten Steel from the Ladle into the Moulds



A Piece of White-Hot Steel, Weighing 6,000 Pounds, Entering the Rolls.



Raising a White-Hot Piece of Steel from the Soaking Pits by Means of a Powerful Electric Arm.

usually taken directly either to the hammer shop or to the mills. In either case the billets are reduced to the desired shape and size by being passed between rolls or under the rapidly moving dies of the steam hammer. The completed billets go to the "inspection house," where every bar of steel is examined minutely for all defects before being weighed, marked and shipped.

Open Hearth Process. The open hearth process furnishes about one-third of the steel used to-day. It has, for the past few years, been rapidly crowding Bessemer steel out of the market, as well as making great inroads in the fields formerly occupied by the crucible product.

The cause of this popularity, on the one hand, is that the stock, in many cases, is much sounder and gives better satisfaction than Bessemer—which naturally justifies the small additional expense. On the other hand, experiments have proven that the lower grades of crucible steel can readily be manufactured by the open hearth method without any visible difference except for the very much decreased expense.

The furnaces in which open hearth steel is made, vary in size from five to fifty tons' capacity, the modern ones being of the latter tonnage. In design they consist of an oblong brick structure alike at both ends. As in the case of the blast furnace, every particle of heat is caught and utilized. The air and gas, entering one end of the furnace and being thrown down upon the charge or "bath" by the curvature of the roof, dart across the furnace or hearth, making their escape through the ports on the opposite side, into the reheating chambers below. Thoroughly heating these, they finally pass up the stack. At regular intervals the air is allowed to circulate through the previously heated chambers prior to its entrance

A Car of Ingot Moulds.

into the furnace, the escaping gases entering and heating the opposite or cool set.

The bottom or hearth, which converges to one point in the center of the furnace, thus facilitating the tapping, is usually lined or covered with a special material, dependent upon the nature of the chemical reaction desired. If a basic reaction—one in which some of the foreign substances are eliminated or reduced—is desired, a basic lining is placed upon the bottom. This usually consists of dolomite, although magnesite, chromite, and lime have been used in a few cases. These materials are able to withstand the strong basic slag. In the acid process, where the phosphorus and sulphur are but little affected by the chemical reaction, a sand lining is usually employed.

During the past few years the open hearth plants have been entirely revolutionized. Whereas, in former days, the pig iron was charged in a cold state, to-day it is almost universally poured into the furnace in its maiden liquid condition, thus economizing in heat, labor, and time in melting.

By the present methods, the large ladles of iron are carried directly from the blast furnace to the mixer. They are next inverted, and their contents gradually poured in. Receiving as i does the products of the various casts of the blast furnaces, the mixer acts as an immense storage room, at the same time thoroughly mixing the several casts together, forming a uniform, homogeneous mass.

When the iron is required in the open hearth or Bessemer departments, the large furnace is swung down upon its axis, permitting the molten metal to flow through the mouth into the ladles standing upon the floor below.

The open hearth furnaces are charged with all manner of scrap, old castings, rails, etc. As required, the desired quantity of each ingredient is placed in large cast-iron charging boxes similar in shape to a bath-tub, having a capacity of about 5,000 pounds each. These in turn are picked up and placed sidewise upon small, flat, narrow-gauge cars. When a sufficient amount to make a charge has thus been collected, the cars are drawn into the building, close to the front of the furnace. The furnace being ready for charging, the immense electric charging machine is brought into action.

By means of this wonderful device, one man, who manipulates the electric levers, can charge a furnace in less than twenty minutes, whereas, a few years ago, this was the work of several hours for a large army of men.

The "acid" process is practically no more nor less than a case of oxidation, in which the phosphorous and sulphur of the charge are not removed, but the steel continues to hold almost every atom of these ingredients as they were present in the iron, scrap, and ore. So the composition of the raw stock, as regards these two elements, must be positively ascertained; and if a low phosphorus and sulphur steel is desired, the charge must be regulated accordingly. On the other hand, the carbon, manganese, and silicon contained in the raw stock are oxidized.

White-Hot Ingot of Steel Being Delivered to the Rolls.

In this process the iron is usually charged first (though many plants charge the stock or scrap first), care being taken to insure its equal distribution over the bottom and on the banks or sides, the scrap being placed as evenly as possible over the iron, thus permitting the scrap to melt first and trickle over the hot iron, the latter being thus protected by the carbon and silicon, for which oxygen has a greater affinity than for iron.

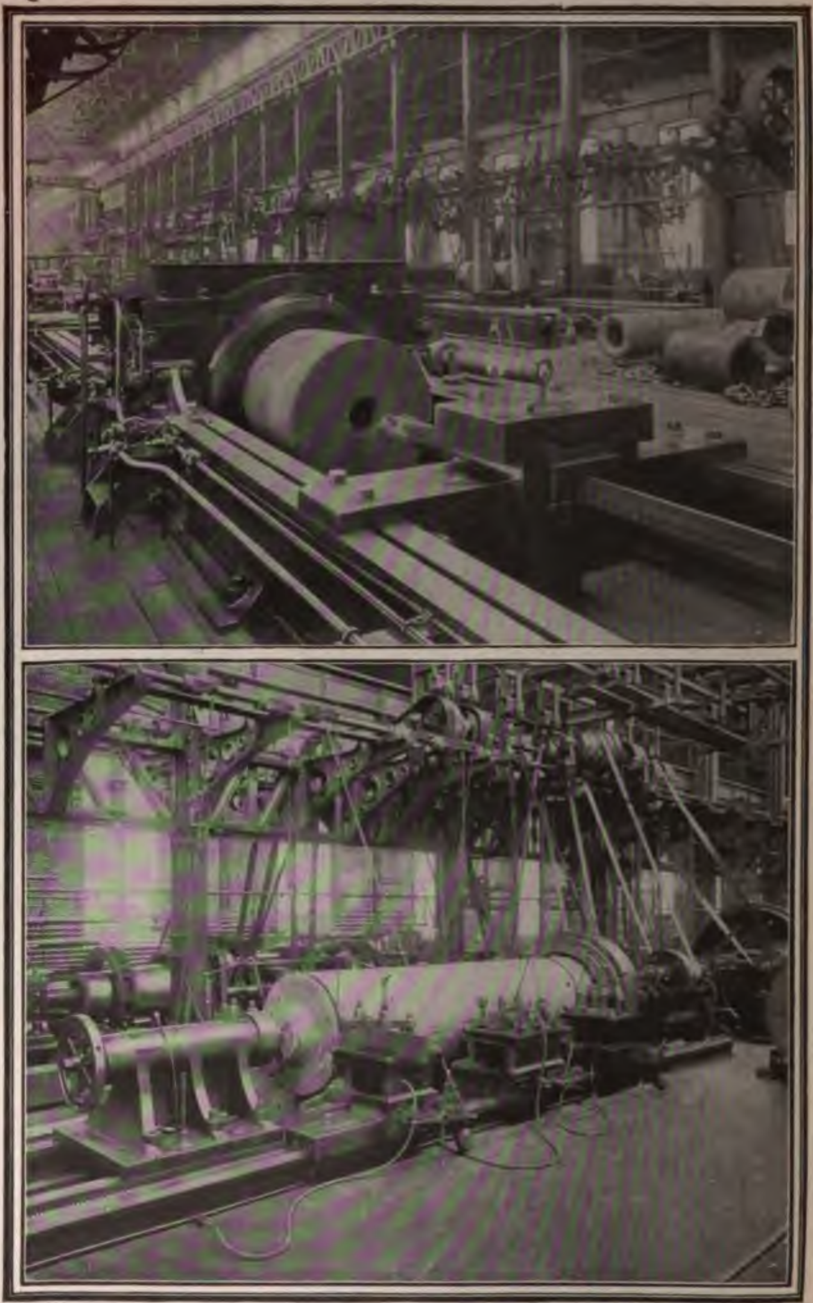
After the metal becomes molten, a covering of slag forms upon the bath, due to the sand from the pig iron if the iron has been charged in the form of sand-cast pigs, and to the silica produced by oxidation. If the pig iron is free from sand and low in silicon, the slag will be very thin and of a basic nature, which would ruin the bottom. As a result, an addition of silica would have to be made. If the opposite, iron is usually added, which forms an iron oxide.

When the entire bath has been melted, iron ore is added at intervals, thus oxidizing the carbon, manganese, and silicon, and forming silica and oxide of manganese, which pass into the slag, while the carbon forms carbonic oxide which unites with the flames. The carbon thus causes the entire bath to bubble, which exposes the metal to the flames and keeps it hot. The metallic iron which is set free by the union of oxygen with the silicon and carbon, is dissolved by the bath.

At intervals a small cup is placed in the bath, and a test of the steel poured into small test ingots about one inch square in cross-section. After chilling in water, these ingots are broken, and the percentage of carbon is determined by the eye. If too high in carbon, the molten mass is oxidized still more; if too low, iron is added.

When the desired point is reached, ferro-manganese or some other recarbonizer is thrown into the bath, the furnace being tapped instantly and the steel permitted to run into the ladle. If this is not performed at once, the manganese will become oxidized through the intense heat of the flames and the slag.

Bessemer Process. Although there are two kinds of Bessemer steel, the "acid" and the "basic," the acid process is the one almost altogether employed, the conditions in this country proving adverse to the basic. In a nutshell, the Bessemer process consists



CUTTING AND BORING A FLUID-COMPRESSED INGOT
BETHLEHEM STEEL WORKS, N. Y.

in forcing a strong blast through molten pig iron, thus oxidizing the carbon and leaving the iron free from the same. In order to recarbonize it to the required percentage, ferro-manganese, coal, or Spiegel is added, while the molten iron is being poured into the ladle.

The furnace itself consists of an iron-covered, brick-lined, pear-shaped vessel suspended upon standards by means of two trunnion arms attached to the converter. By this means the vessel can be rotated almost seven-eighths of a revolution, thus permitting it to be placed horizontally on one side to be filled, then perpendicularly or vertically to be blown, horizontally on the opposite side to be emptied, and upside down to permit the slag to run out.

The charge of five to twenty tons of molten iron, taken either from the mixer or from a cupola, being introduced, a strong blast of air of fifteen to twenty pounds' pressure per square inch is permitted to rush through one of the trunnions into the small chamber in the bottom of the vessel. From here it makes its exit into the interior of the vessel through the numerous small holes in the false bottom. At the same instant, the vessel revolves and points its mouth upward. Here it remains for several minutes, the first four or five minutes witnessing a flame of light yellowish-red color and a shower of glittering sparks. During this stage the uncombined or graphitic carbon passes into combined form, the silicon being oxidized to form silica, which unites with ferrous and manganous oxides to form slags. This change is accompanied by a rapid rise of temperature, the flames becoming brilliant, large, and of a very dense yellow color. The metal now boils, the agitation being due to the formation of carbonic oxide from the oxidation of the iron by the oxygen of the blast. During this stage the pressure of the blast is reduced.

The next stage in the process is signaled by the pale rosy hue of the flame, which becomes more transparent and less brilliant, together with the small number of sparks now issuing from the vessel.

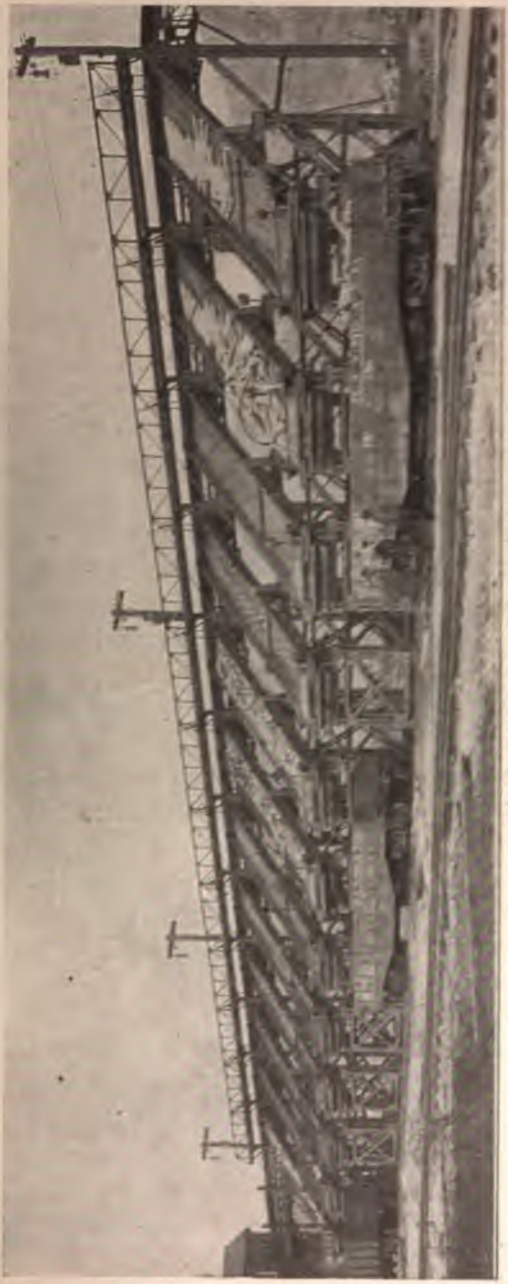
These are signs that the carbon is nearly eliminated and the contents of the vessel almost ready for the last steps. When the flame drops, the vessel is at once turned down, and the blast shut off. Its contents are then poured into a ladle; and at the same time, a certain percentage of Spiegel or ferro-manganese is added, in either cold or liquid state, to recarbonize the metal to the required amount. The phosphorus and sulphur in the steel are practically the same as in the iron before blowing, the silicon, carbon and manganese having been reduced.

Quickly the vessel is turned over, filled, and the operation repeated; the ladle containing the molten steel being lifted by the hydraulic crane over a set of moulds, into which the newly made steel is poured. As soon as filled, a little locomotive carries the long row of cars upon which the freshly cast steel ingots and their moulds are resting, to the open yard beyond.

Shearing the Large Slabs of Steel While Red-Hot.

After the moulds have been filled with the molten steel, they are taken to the "stripper," which is usually next to the open hearth or Bessemer buildings. Here the cars containing the moulds are run under a large electric crane, which is so constructed that two arms fit over a projection on each side of the mould. As the mould is lifted, a central ram presses upon the top of the ingot, leaving the ingot upon the car, while the mould is picked up and placed upon a car located upon the next track.

From here the red-hot ingots are taken to the heating fur-



A New Method of Loading Steel Billets.

naces of a plate or "blooming" mill, where they are heated to a higher temperature for rolling. When of the proper heat, they are lifted out of the large furnaces by means of an electric crane and are carried to the table.

The latest method of transferring the ingots from the soaking pits to the rolls is by lifting them one at a time from the furnaces, as above stated; but instead of carrying them to the rolls by the crane, they are placed on end on a specially constructed cast-iron car operated by electricity. The car is then run to the end of the table, where a lever attached to the rail throws the body of the car towards the rolls, the ingot falling upon the table. The car then returns for another load.

The rolls rotating, the ingot is advanced towards the large rolls through which it is to pass. Faster and faster revolve the small rolls, carrying the heavy solid block of steel towards the large rolls. Through these it goes, throwing its scale in every direction. The ingot having reached the other side in a somewhat flattened condition, the engines stop and reverse, the table again carrying the ingot between the rolls. Backward and forward it passes, each pass reducing its shape and thickness until of the proper dimensions, when it is carried between the powerful teeth of the shears which cut it to the desired lengths.

If billets are being made, they are conveyed as rapidly as sheared, by means of an endless chain, up an incline to the top of the bins. Here is a long, narrow platform over which the chain travels. Along the side of the platform are the steel bins, with gates at both ends. The bottoms of the bins slant at an angle of sixty-five degrees from the chain to the ground. The billets, being carried up the incline and along the narrow platform, come in contact with the switch or upper door of the bin, which opens and allows them to enter. One after another they go tumbling down; and when the bin is filled, that gate is closed and the door of the next bin opened. When the billets have cooled, the lower gates are opened, and the billets fall into the cars beneath. Thus the steel is made, taken from the moulds, heated, rolled, cut and loaded, without the actual touch of man.

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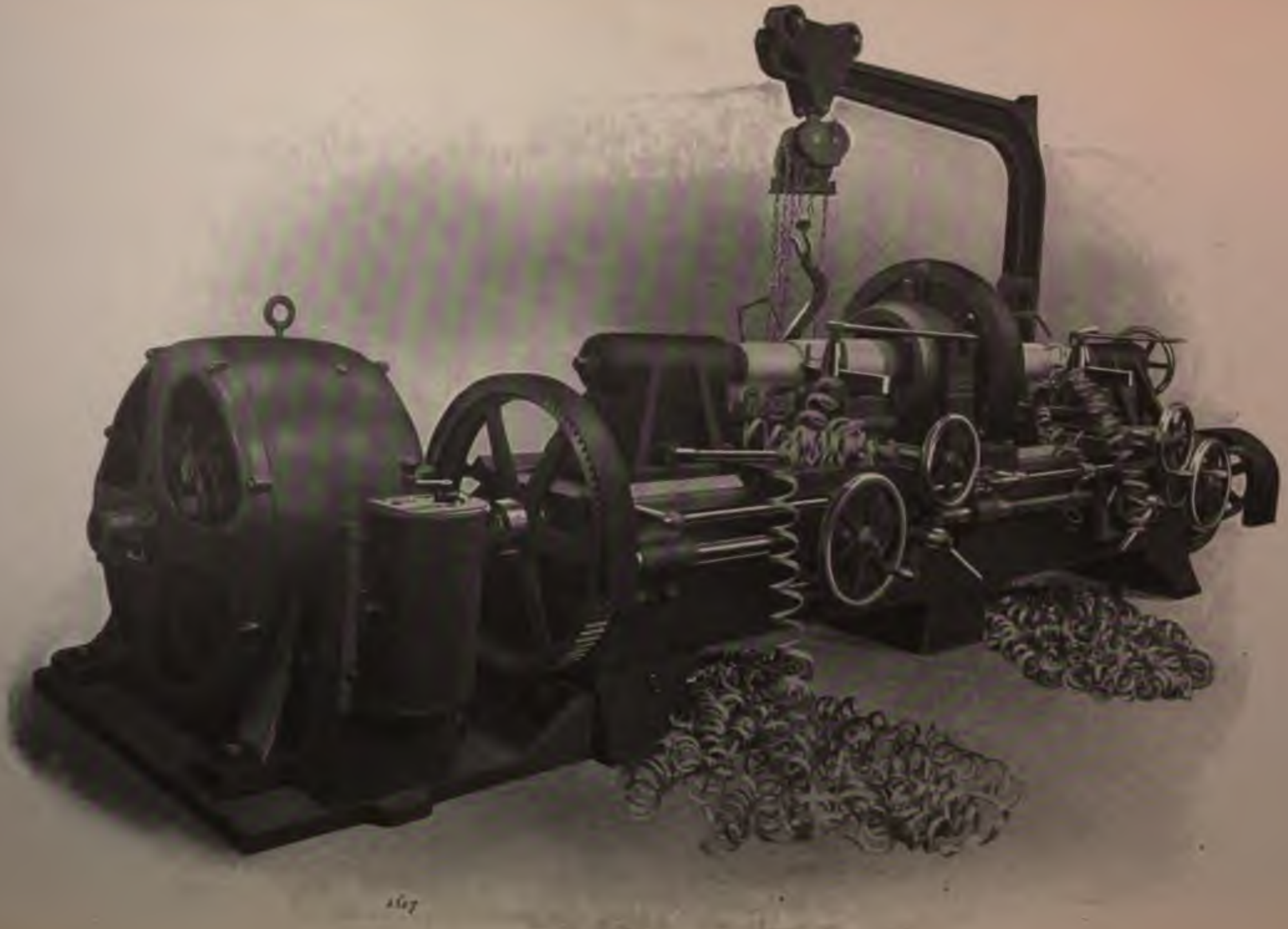
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THE ECONOMY OF HIGH-SPEED STEEL.

In the finishing process in the machine shop, there has been a wonderful development, during the past few years, in the rapidity with which metal can be removed, as well as in the character of the surfaces obtained. For many years, tools made from cast steel, crucible steel, or tool steel (all these names referring to steel of practically 1 per cent carbon), were the only tools that could be employed in the machine shop for the removal of metal. The good old tempered steel tool did its work well, and, in spite of the development of other steels, it has not by any means been entirely superseded. One of the great advantages of the old carbon tool steel is that its manufacture and use have covered so long a period of time that the quality of the steel in the bar, and the results obtained by the shop smiths, have become very uniform.

Tungsten Steel. The first indication of improvement on carbon tool steel, in the line of ability to "stand punishment", was the introduction of the so-called "Mushet" steel, some fifteen or twenty years ago. This was a steel containing, in addition to the elements usually found in tool steel, a certain percentage of tungsten. The name "Mushet" was applied to the steel on account of the fact that R. Mushet of Sheffield, England, was the most prominent manufacturer of this grade. Tungsten steel has several peculiarities that distinguish it from carbon steel. It is an extremely hard steel, and cannot be easily forged. It has the peculiar property of being always hard; that is, when heated and forged, it resumes its hard condition after slow cooling. Dipping it when at a red heat, in water, will almost invariably cause the steel to fly in pieces. On the grinding wheel, tungsten steel shows a dull red spark entirely different from the spark given off by carbon tool steel. Owing to its permanently hard condition, forging and grinding were the only processes by which tools could be shaped, and consequently this steel was used for lathe and planer tools almost exclusively. During recent years, methods have been found for annealing tungsten steel to a limited degree, so that its use is no longer limited by its hard and brittle nature. Another point of difference that calls for consideration is that of price.

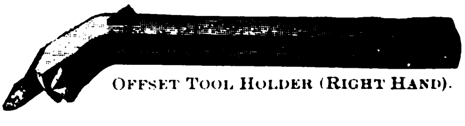
meant use where the results are clearly superior to those obtained by the employment of the cheaper and slower working steels.

On account of the high price of these improved grades, it has been found economical to use the steel in small sections which can be carried in a case-hardened mild-steel holder. Typical examples are shown in the accompanying illustrations. While these holders are very handy, and certainly save large amounts of costly steel, still they cannot be made as rigid as a solid forged tool; and, for the very heaviest work, a tool forged from the solid is still preferred. High-speed steel, however, is very brittle, and, if forged solid, should be carried out to the cutting edge in as large a section as possible. If used in a holder, it must be supported very nearly out to the cutting edge.

OFFSET TOOL HOLDER (LEFT HAND).

Holders for this costly steel usually provide means of clamping by a set screw. Some method of doing away with the vibration inseparable from a screw is desired; and it has been suggested and proven to be good practice to solder or braze small pieces of high-speed steel onto soft-steel shanks. This has in many cases proved very satisfactory.

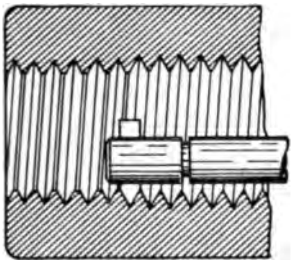
The Test of Results. There have been so many extravagant claims made in regard to results alleged to be accomplished by the use of high-speed steel, that many men have concluded that this steel could not possibly fulfill them. As a matter of fact, in many cases cited, it cannot. Actual results, however—sufficient to establish the economy of these steels—can be obtained in abundance, and a few general figures on relative speeds may prove of value. With ordinary carbon-steel tools, an average figure for the cutting speed would be about 20 feet per minute for mild steel, 30 feet per minute for wrought iron, and 40 feet per minute for cast iron. These figures, of course, are merely approximate, but they fairly represent



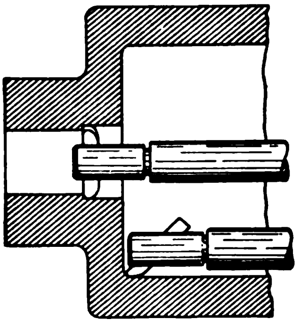
OFFSET TOOL HOLDER (RIGHT HAND).

average practice. By the use of tungsten steel, the speed for roughing cuts was increased about fifty per cent, while heavier cuts, also, could at the same time be taken. The later high-speed steels, however, show great improvement over these figures, the speed for roughing cuts being increased to about 50 feet a minute for mild steel and wrought iron, and 75 to 80 feet per minute for cast iron. Finishing cuts, especially for mild steel, can be taken at rates which appear to be little short of marvellous, a speed of from 150 feet to 200 feet per minute being not uncommon in the finishing of mild steel.

One of the peculiar things connected with the development of high-speed steel, has been the simultaneous development of grinding. The process of grinding has no place in this article, but it may be noted that the high-speed steels are being extensively used for roughing cuts, while the finish is obtained by grinding. As an instance of work of this character might be cited the turning of cast iron at a cutting speed of 75 feet per minute—depth of cut $\frac{1}{8}$ inch, with a feed of $\frac{1}{4}$ inch per revolution, leaving $\frac{1}{32}$ inch over the correct size at the bottom of the groove. The finish obtained by grinding is superior to, and more rapid than, that secured by fine turning, filing, and polishing.



TOOL CUTTING A THREAD.



DOUBLE-ENDED CUTTER ROUGHING OUT CORED HOLE. ALSO ANGLE CUTTER BORING AND FACING END.

People have become discouraged in some instances, possibly, disgusted-- with high-speed steel, on account of the oft-prevailing tendency of human nature to wish to get something for nothing. There are many brands of this steel, and the methods of working, especially as far as the heat treatment is concerned, are as numerous as the steels themselves. Nearly all steel salesmen, even if they d sist on leaving a sample of their steel, are perfectly willing) so; and the result is the tool room soon acquires a colle from which the identifying marks are almost sure to be . reupon there is trouble for the tool dresser and the ma . It is not intended by this to advise the exclusion of new materials and processes, but more particularly to recommend keeping the experimental and the commercial ends of one's business separate and distinct from each other. It is well to try thoroughly all brands of steel offered; but it is not wise to have more than one brand for shop use.

The steel salesman, also, in numerous instances, is inclined to make claims for his particular brand, which claims, in many cases, cannot be substantiated. This does not imply that the results will not show a distinct advantage over the old carbon steels. The purchaser should not expect to obtain results fully equal to those claimed by the agent, the claims of the salesman being generally based on short laboratory tests, and sometimes, it is to be feared, colored to suit the prospective purchaser. If a substantial saving in time can be made, there is economy in the use of high-speed steel, and the fact that still better results than this are claimed, does not prove that its use is not economical.

There is an economy in the use of this steel, which, while it may be attributed to the material, is in a sense not directly concerned with its use. It is a well-known fact that so simple a matter as speeding up the shafting has a tendency to quicken the life of the whole shop. This is true not only as regards the actual output of the machines; but it also actually quickens the physical movements and mental grasp of the workmen themselves.

In a recent address before an engineering society, a speaker used this expression, "High-speed steel is developing high-speed machinists." This remark is strictly true; and, although the introduction of this steel will be opposed by the slothful workman, its influence upon the great majority of men will be distinctly beneficial.

To sum up in a word, the economy of high-speed steel may be said to comprise saving of time in the machine operation; better mechanical results, especially if we include the simultaneous development of grinding; and finally—perhaps the most important of all—the quickening, physically and mentally, of the workman.

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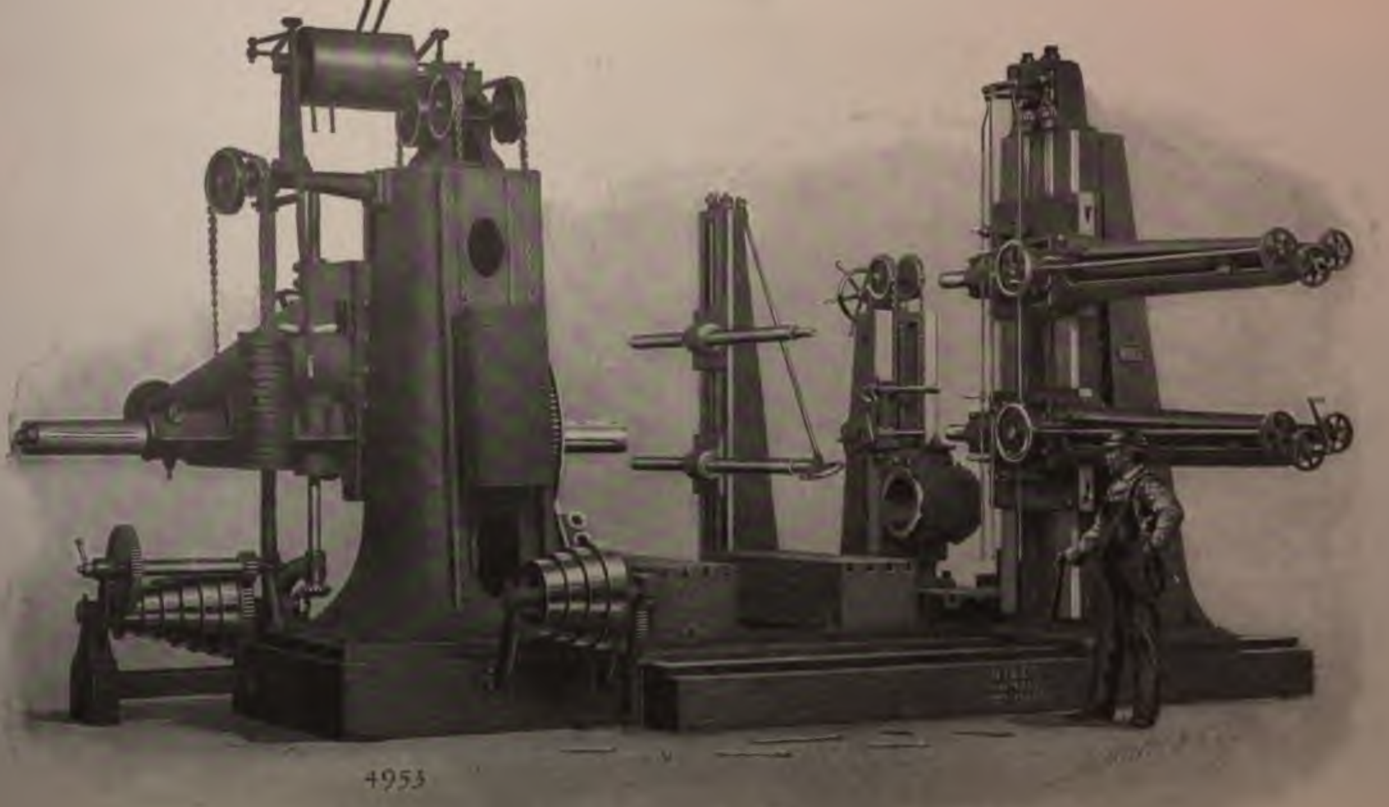
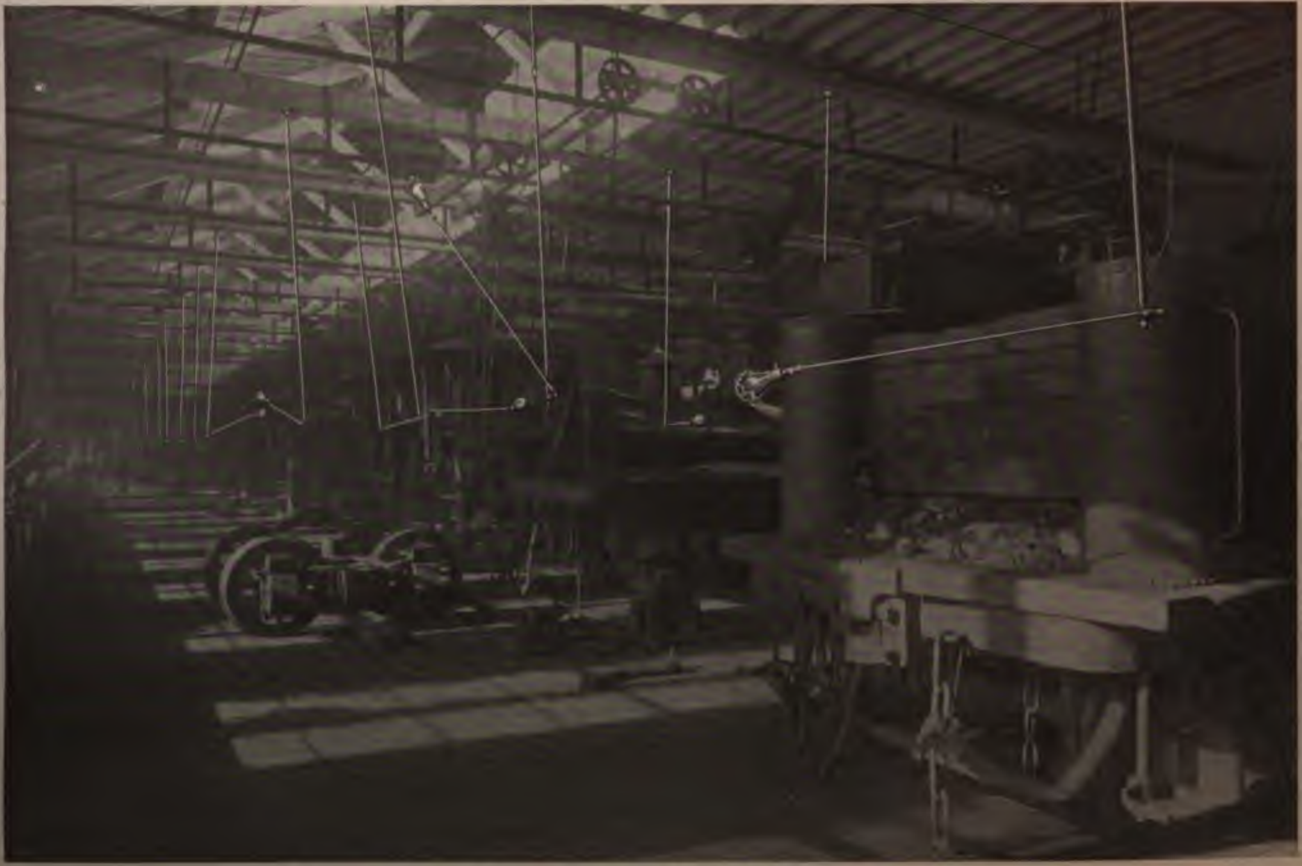


CYLINDER BORING MACHINE WITH PORT BORING ATTACHMENT.

SHOP LIGHTING.

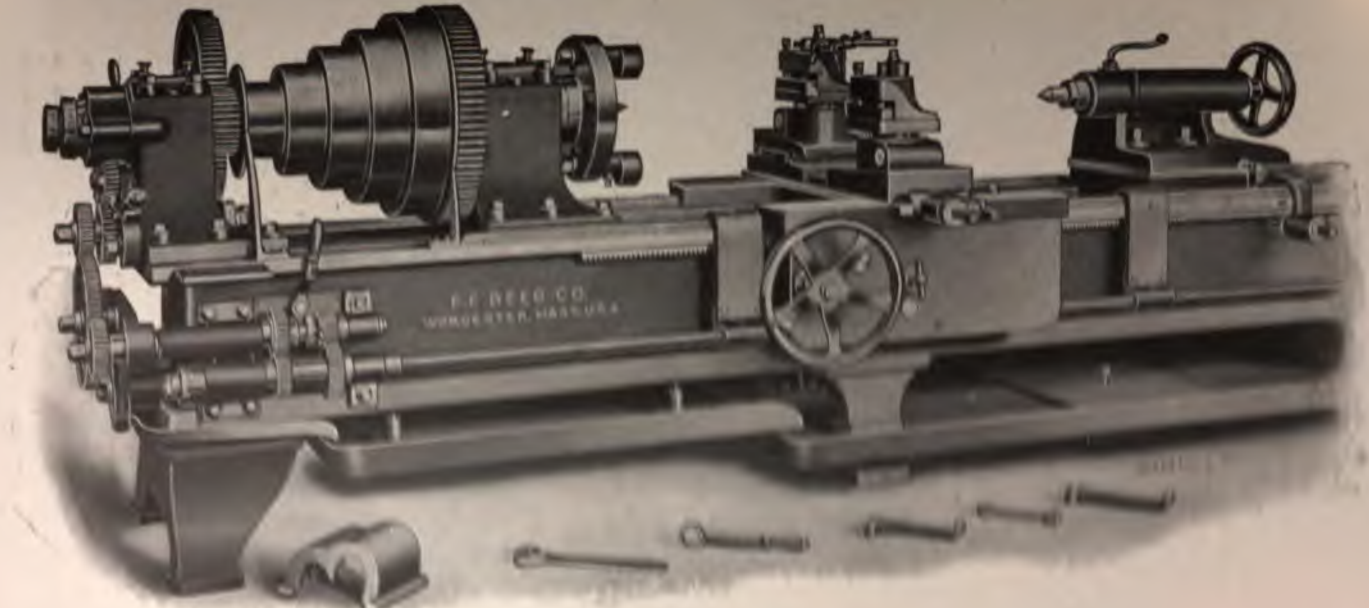
It is only within a few years that what is now regarded as proper attention to lighting has been considered in the design and construction of factory buildings. Formerly, a shop seemed to be designed more to protect the tools and materials from the weather, than to afford any degree of convenience or comfort for the workmen. It is now regarded as good business policy (in other words, it pays) to provide buildings which are properly heated, lighted, and ventilated. In such buildings, it has been found that workmen are more content, do better work, and produce more. From the old-fashioned blacksmith shop, in which each smith was supposed to work by the light of his own fire, it is a far cry to shops such as those of the National Cash Register Company at Dayton,

BOSTON & ALBANY RAILROAD MACHINE SHOP, WEST SPRINGFIELD, MASS.
Equipped with White Adjustable Fixtures.



INTERIOR OF REPAIR SHOP, BOSTON AND ALBANY R.R., ALLSTON, MASS.

Incandescent Lights with White Adjustable Fixtures



24-INCH SPECIAL LATHE.
F. E. Reed Company.

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Ohio, in which the comfort and convenience of the employees has been given a degree of attention that seems to the old shop managers to partake of the nature of coddling.

DISTRIBUTION OF SUNLIGHT.

In considering this question of lighting, it is well understood that daylight is the best light, especially when it is not accompanied by the direct rays of the sun. To properly distribute daylight—which is, of course, the cheapest light—over large areas, is the first problem to be considered in the design of new shop buildings. This may be accomplished in a number of ways. Where buildings are several stories in height, and where light, except in the upper story, must be admitted from side windows, those windows should reach from the top of the bench to the ceiling. A given amount of glass arranged in this manner gives a much better general distribution of light than the same amount of glass put into the ordinary form of short windows. The amount of light in the center of the room depends very largely upon the height of the windows at the side. All modern factory buildings

WHITE ADJUSTABLE FIXTURES IN WORCESTER SAFE DEPOSIT & TRUST COMPANY, WORCESTER, MASS.

are now lighted by long, narrow windows. The common type of shop, consisting of an open floor with a gallery on both sides, is usually lighted, in addition to the tall side windows, by glass in the sides of the monitor roof. If these monitor windows are kept clean, they add greatly to the light of the main floor.

The best system of roof lighting is by means of what is termed a "saw-tooth" roof, the short and comparatively steep side of the tooth being composed wholly of glass. This glass should face as nearly north as possible, in order to avoid the direct sunlight. In this connection, it will be remembered how the workmen of the old school, especially if employed on work requiring close application, always selected a north window, even if the view therefrom was not so pleasing as that from some other point of the compass. This saw-tooth roof may be used on the top of a monitor in place of side windows, and it results in a much better lighted floor.

WELSBACH BURNER.
With silvered glass reflector.

Old shops, in which a change in amount or location of glass area is impossible, can have their light increased in amount and better distributed by a judicious arrangement of machines, and, particularly, by keeping the walls and ceilings as nearly pure white as possible. Whitewash is so cheap and so easily applied by modern pneumatic methods, that there is little or no excuse for neglect in this particular. Whitewash can easily be made so that it will not readily rub off, in fact, so that it can be washed; but in most cases a fresh application is preferable to cleaning The removal of all possible belting (which can be accomplished by electric driving, either individually or by the group system) adds largely to the lighting effect, and also, by the suppression of dust and flying oil, keeps the walls and ceilings in much better condition. Some factories carry this whitening effect to the point of having the machine tools painted white and varnished. This not only avoids dark spots in the room, but shows plainly any neglect of machinery. In a shop equipped in this manner, the dirty and slothful workman is entirely out of place, and he usually changes his habits or seeks some other shop where his natural conditions prevail.

ARTIFICIAL LIGHTING.

Artificial lighting, which is usually required in northern latitudes, may be divided into three classes: General lighting, individual lights, and portable lights.

Lighting by candles, except in some cases of portable lights, has entirely disappeared; but many country shops still have to depend upon oil as an illuminant. In such cases, large lamps of the Argand type are suspended from the ceiling for general illumination, and small flat-wick lamps, preferably on swinging wall brackets, are used for the individual. The quality of this illumination depends, first, upon the care of the lamps, and, second, upon the quality of the oil. Oil lights at best are dirty and entail a large amount of labor. They are objectionable in that they must be kept from draughts of air, which smoke the chimneys, and thus the shop is often deprived of proper ventilation.

Gas is more frequently used for shop lighting than any other artificial illuminant. It may be classed under the heads of oil gas, coal gas, natural gas, and acetylene. For the isolated shop, oil gas and acetylene are particularly adapted, as such gas plants are easily installed and require but little attention. In every case, the gas plant should be entirely separate from the factory building, and preferably under ground. While acetylene furnishes a light almost ideal in character, it is particularly poisonous, although leakage is readily detected by its odor. A more serious drawback is that this gas forms violently explosive compounds when mixed with air in comparatively small proportions. Many serious and some fatal accidents have occurred by failure to realize the importance of this fact. These installations should be made only by those thoroughly familiar with the subject, and their use must be carefully guarded.

Coal gas is very largely used for shop lighting, on account of its comparative cheapness and the fact that, even in small cities, it can be readily obtained. As it is also used in many shops for heating, in connection with the Bunsen burner and blowpipe, it serves a double function which renders it peculiarly adapted for factory purposes. The ordinary open fish-tail burner, consuming about six cubic feet per hour, is the type of burner generally used. This light is objectionable on account of the fact that it vitiates the air; this, in the winter months when the windows are closed, becomes a serious matter, and calls for largely increased ventilation. The light flickers, even in still air, which makes it very trying to one's eyes when engaged on fine work, and this difficulty is further increased by currents of air caused by open windows or moving belts.

ORDINARY WELSBACH BURNER.

THE WELSBACH BURNER.

Ordinary illuminating gas used in connection with a Welsbach burner, furnishes a very steady light with about one-half the gas consumption necessary for the open light. The Welsbach light is best suited for general lighting, where two or more burners are contained in the same globe and suspended from the ceiling. As an individual light, the Welsbach is not in great favor, on account of its ghastly color combined with a faint tinge of green, which renders it objectionable to many workmen. The mantle used in the Welsbach light is extremely fragile, and it is quickly put out of commission by shocks, vibration, and air currents. For these reasons it is not so well suited for use in the shop as it is for domestic purposes. The Welsbach light, however, is not dependent upon the illuminating quality of the gas, but upon the incandescence of the mantle, which may be produced by any form of fuel gas without the enriching necessary to make it suitable for use in an open burner. Natural gas, therefore, which is used for heating in many sections of the country, can also be used for lighting if employed in the Welsbach burner. As this gas is very cheap, it often pays to use it in this manner.

Open—Arc Lamp, Double. Old Style.

Open—Arc Lamp, Single. Old Style.

White Adjustable Ceiling Fixture for Incandescent Light. Style A.

ELECTRIC LIGHTING.

Electric lighting is rapidly being introduced for shop purposes, especially when the current is generated in the factory. The arc light is commonly used for general illumination, and the incandescent light for the individual. The open arc light is being supplanted by the enclosed arc, with a distinct gain in economy and safety. The open arc, even with the best quality of carbon, is somewhat noisy, and is subject to disagreeable flickering, while the falling of pieces of incandescent carbon, is not only annoying, but dangerous. The enclosed arc light requires less frequent trimming, is more steady, and owing to the fact that it is enclosed, it absolutely prevents danger from falling particles of carbon. Arc lights for general illumination are usually in the vicinity of 1,200 candle-power.

ENCLOSED ARC LAMP.
GLOBE IN TRIMMING POSITION.

WESTINGHOUSE SERIES—ALTERNATING ENCLOSED-ARC LAMP.

The 16-candle-power incandescent lamp is generally used for individual light; but the 8-candle-power lamp, with a suitable reflector, is less dazzling and furnishes all the light necessary. The

WHITE ADJUSTABLE BENCH FIXTURE
INCANDESCENT LIGHT. Style D.

system adopted in some drafting rooms, of using an inverted arc—that is, one with the crater in the lower carbon—combined with a reflector to throw the light directly to the ceiling, results in a uniformly diffused light. This avoids the sharp shadows cast by the direct light from the arc, and has much to recommend it as a shop light, especially if the ceilings and walls are kept white.

There are several styles of fixtures used in connection with the incandescent light to place the lamp in any desired position, as the ordinary drop light is very inconvenient in this particular. The White fixture, with its ball-and-socket joint, is one of the best.

In connection with the question of electric lighting, the necessity of maintaining a constant voltage is one that is not given the

COOPER HEWITT LAMP FOR GENERAL INTERIOR LIGHTING.
Type H 7, an improved form of Type V 5. Can be operated in horizontal, vertical or inclined position.

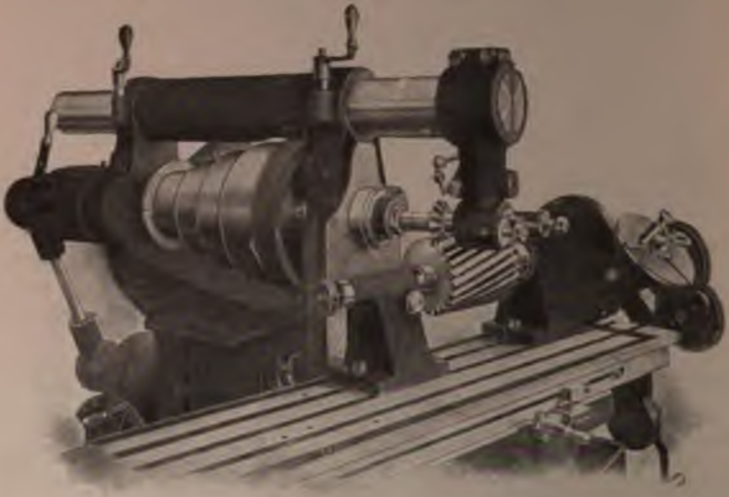
attention it deserves. It is almost impossible to secure satisfactory lighting from a generator driven by the main engine, and this is especially true if electric cranes are also operated from this generator. In the best practice it is considered necessary to have a separate engine and generator to be used solely for the lighting system. A generator driven by the main engine is found satisfactory for crane service.

COOPER HEWITT LAMP FOR INTERIOR LIGHTING WHERE MODERATELY STRONG ILLUMINATION IS DESIRED.

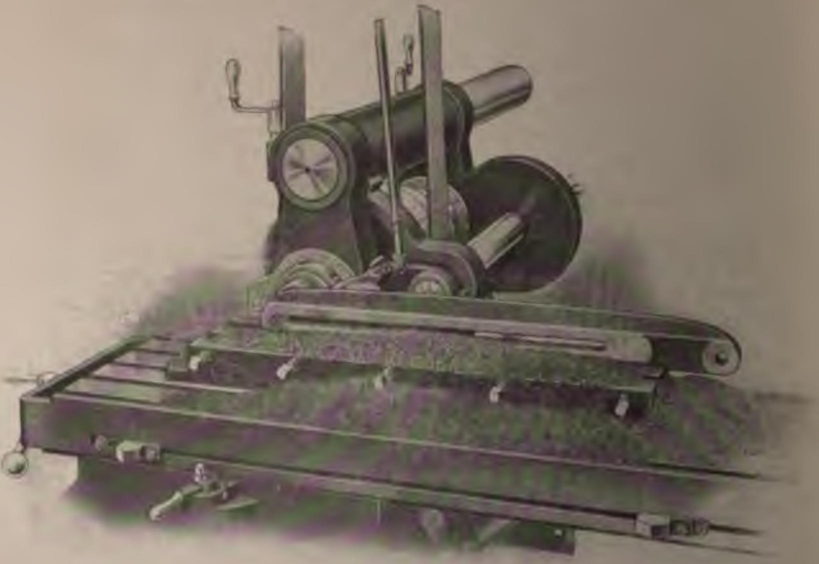
Designed for series installation—two in series on 100 to 120 volts direct current. Suspended at an angle of 20° from ceiling or fastened to wall. Type H 6.

The Cooper Hewitt Light. The Cooper Hewitt mercury vapor lamp is the cheapest form of electric lighting, and will undoubtedly be the commercial light for factory use, especially in shops doing a fine class of work. The color of this light, due to the total absence of red rays, is objectionable but not injurious; and further experiments will undoubtedly produce a light based on this principle which will meet many requirements

For portable lighting, there is nothing at present superior to the incandescent lamp, for, by means of a long flexible cord, it can be taken to any position. The incandescent lamp, furnished with a magnetic base, can be attached to any iron or steel surface, where it will remain until the light is extinguished. For erection work, particularly, this type of lamp is peculiarly adapted.



CUTTER 8 IN. DIAMETER. SPEED 40 FEET PER MINUTE.



CUTTER ¾-IN. DIAMETER. SPEED 83 FEET PER MINUTE.

Examples of Plain Milling.

Cincinnati Milling Machine Co.

THE VERTICAL MILLING MACHINE

Among the many new machines that have been built and put on the market within the last decade and a half, we doubt if any has become more indispensable to the manufacturer of machinery of every description than the Vertical Milling Machine. Its advantages over even the latest designs of the horizontal type are now universally recognized for many classes of manufactured work. For finishing surfaces—usually done on the planer or shaper or in the lathe—the vertical milling machine fills a place in general manufacturing plants with absolute success. For circular or straight work, for finishing surfaces both horizontal and vertical that are either difficult or impossible to get at with lathe or planer, the vertical machine has no equal. It is impossible to exaggerate its utility as an economizer of labor and as a producer of work impossible to perform with other tools.

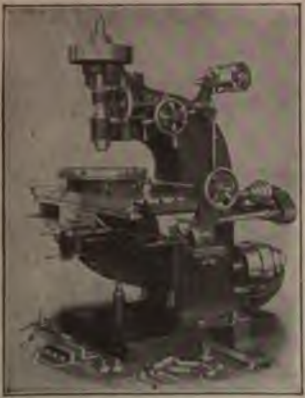


Fig. 1. Modern Vertical Milling Machine.

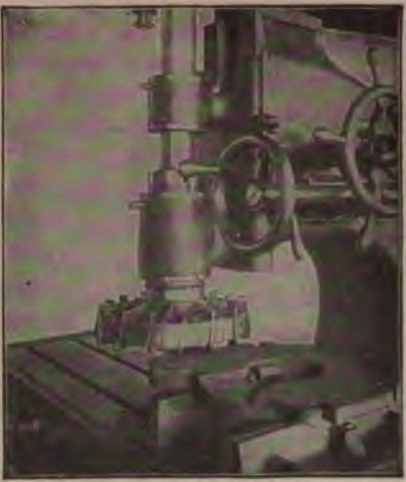


Fig. 2. Facing a Plane Surface with Inserted-Tooth Tool.

In Fig. 2 is shown a twelve-inch inserted-tooth face mill, roughing off a plane surface, and this also shows the correct practice in using cutters of this kind on a vertical machine. The cutter is fitted to the nose of the spindle which secures great rigidity. Its economy over a planer in this class of work is from three (and even more) to one; and if the parts have to be scraped to a fit or a finish, the labor is reduced in like proportion.

On the other hand, if it is necessary to cut into the recess in the center of the casting, a cutter similar to that shown in Fig. 3 could be used. This style of tool on a vertical milling machine is what might be called a "universal cutter," or "end-and-side" mill; and Fig. 3 shows how it is used on what would be an awkward job to do on the planer. It matters not whether the end of the table to be milled is one or six inches thick; at the lowest estimate the the planer is the loser, three to one. If, for instance, the piece is comparatively short, and requires finishing on both ends, no change of tools is necessary, the table being simply moved along until the other end of the piece is in position to be milled to its proper dimensions.

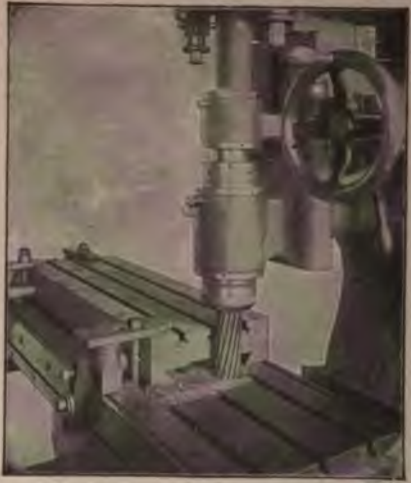


Fig. 3. Universal Cutter for End-and-Side Milling.

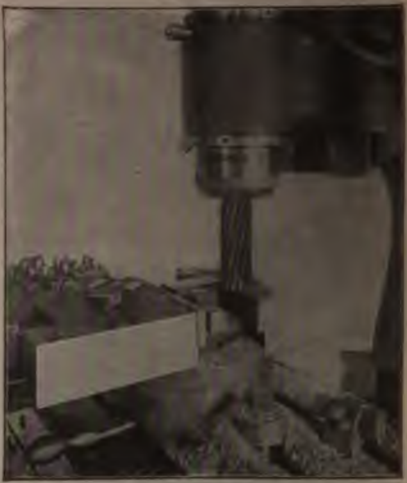
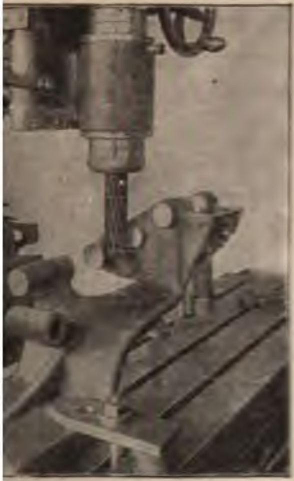


Fig. 4. Small Parts Rapidly Finished in Vertical Milling Machine.

The advantage on small pieces, as shown in Fig. 4, is manifest; and the same style of cutter, if used as a combined end-and-side mill, will do more in one hour than could be accomplished by a shaper in six hours. This class of work as a rule uses up much machines that could be employed to better economy on d larger work; while the fact that the same tool can be used king on either side or the surface without change, recommends vertical milling to the up-to-date manufacturer.



Facing Spots at Irregular
rals and at Right Angles.

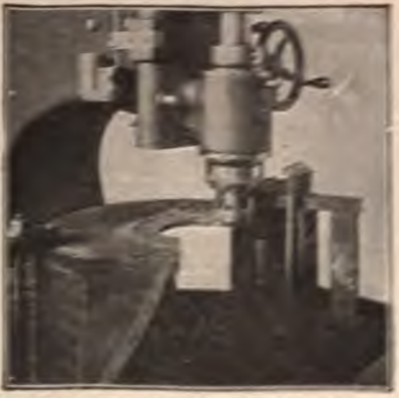
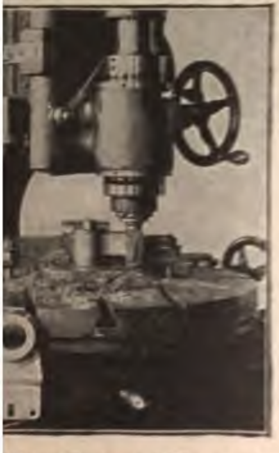


Fig. 6. Finishing Inside Edge of Casting.

Milling or planing spots ne at irregular intervals or at right angles with each other, er been a practical operation in the general run of work n machine shops. The work is usually done by hand, or, quired to be of a better finish, is counter-bored. Take for



ishing Horizontal Plane and
Curve at one Operation.

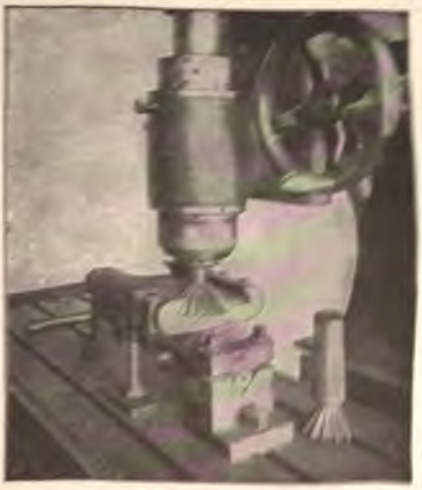


Fig. 8. An Example of Angular Milling.

instance a bracket, as shown in Fig. 5, with spots to be finished on both ends, on the inside, at different levels and at right angles with each other—a difficult subject to handle by any method other than the use of a vertical milling machine. This class of work can be done at an economy of four to one over any other method, with a saving of time on all subsequent operations; and it also insures all surfaces being parallel or square with each other, without changing the setting of the work.

On the piece shown in Fig. 6, the same style of cutter could be used for finishing spots on the inside surface of a casting, or for finishing the top edge of the casting, or the top and sides of the plate, by which it is fastened to the machine. In the hands of a skillful workman, even the outside irregular surface could be easily finished with an economy over any other method, of ten to one.

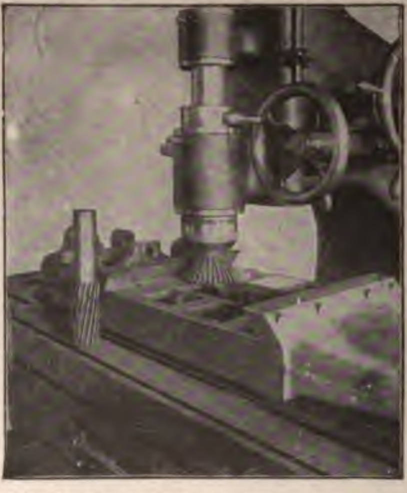


Fig 9. Vertical, Horizontal, and Angular Milling with Two Tools.

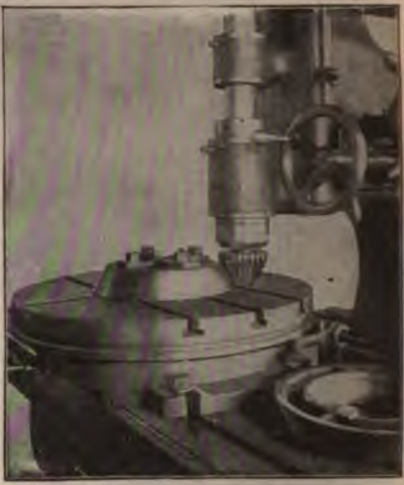


Fig. 10. Circular Bevel Milling.

The universal use of the end-and-side mill in the vertical milling machine is strikingly shown in Fig. 7, where one is used in finishing a horizontal plane surface and the vertical segment of an arc, at one operation and in one-tenth of the time required in a lathe. An end-and-side mill should as a rule be made with special flutes; and, if over one and one-half inches in diameter, it would be of advantage to have the teeth nicked to break up the chips.

Two examples of angular milling are shown in Figs. 8 and 9;

and in each case it may be noticed that there are vertical surfaces to be milled, and also horizontal edges to be finished. These are taken care of, first by the use of the end-and-side mill shown standing on the table in Fig. 9; and then the angular or dovetail mill is substituted, and the under-cut is made. One can readily see that there is no end to the work of this kind that can be done—slotting in places absolutely inaccessible to ordinary methods; under-cutting and bevel or dovetail work in straight line or circle; and inside profile work, either free-hand or by the use of profile pattern gauges. Some of this work can be done by no other method on a machine, and, until the advent of the vertical milling machine, was done by hand. The saving in time on such work will cover the expense of the machine in a comparatively short time, let alone the accuracy and amount of the work performed.

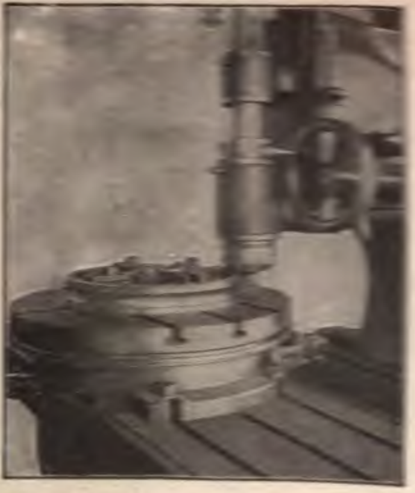


Fig. 11. Ball Cutter Used with Rotary Table.

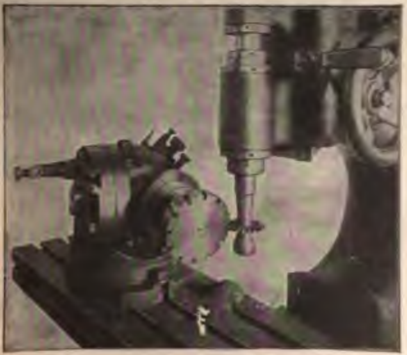


Fig. 12. Method of Cutting Slots Around Edge of Blank.

Fig. 10 shows an example of outside and inside bevel circular milling; and the piece lying on the platen shows also a circular recess done by the end-and-side mill. In fact, all the finish on this piece—top, bottom, inside, and outside—has been done by the use of the bevel and the end-and-side mill, on a power-driven rotary table, at a saving over the method of turning on a lathe, of four-fifths of the cost.

The T-slots in the rotary table are done with a T-slot cutter, The ball cutter used in connection with the rotary table is shown in Fig. 11; and it can be readily seen how the handle, which is connected with the vertical feed of the head, is finished by the use of a concave mill. By using a universal dividing head, all the usual work done on the horizontal milling machine can be done. Fig. 12 shows the method of cutting the slots in the blank for an inserted-tooth cutter to be used on the vertical milling machine.

The use of the vertical milling machine seems to be growing more and more in favor with manufacturers of machinery and hardware sundries. The writer has in mind a case where a large door-frame for a boiler front was to be faced off, and the door milled to fit. The old method was to chip and file until the fit was made, which required nearly three hours' labor for one man. By the use of the vertical milling machine the time was reduced to about twenty minutes. This is only one of many thousands of cases where the supremacy of this machine is so apparent that the manufacturers have been obliged either to introduce it as a money saver in their factories or to continue to be classed as behind the times.

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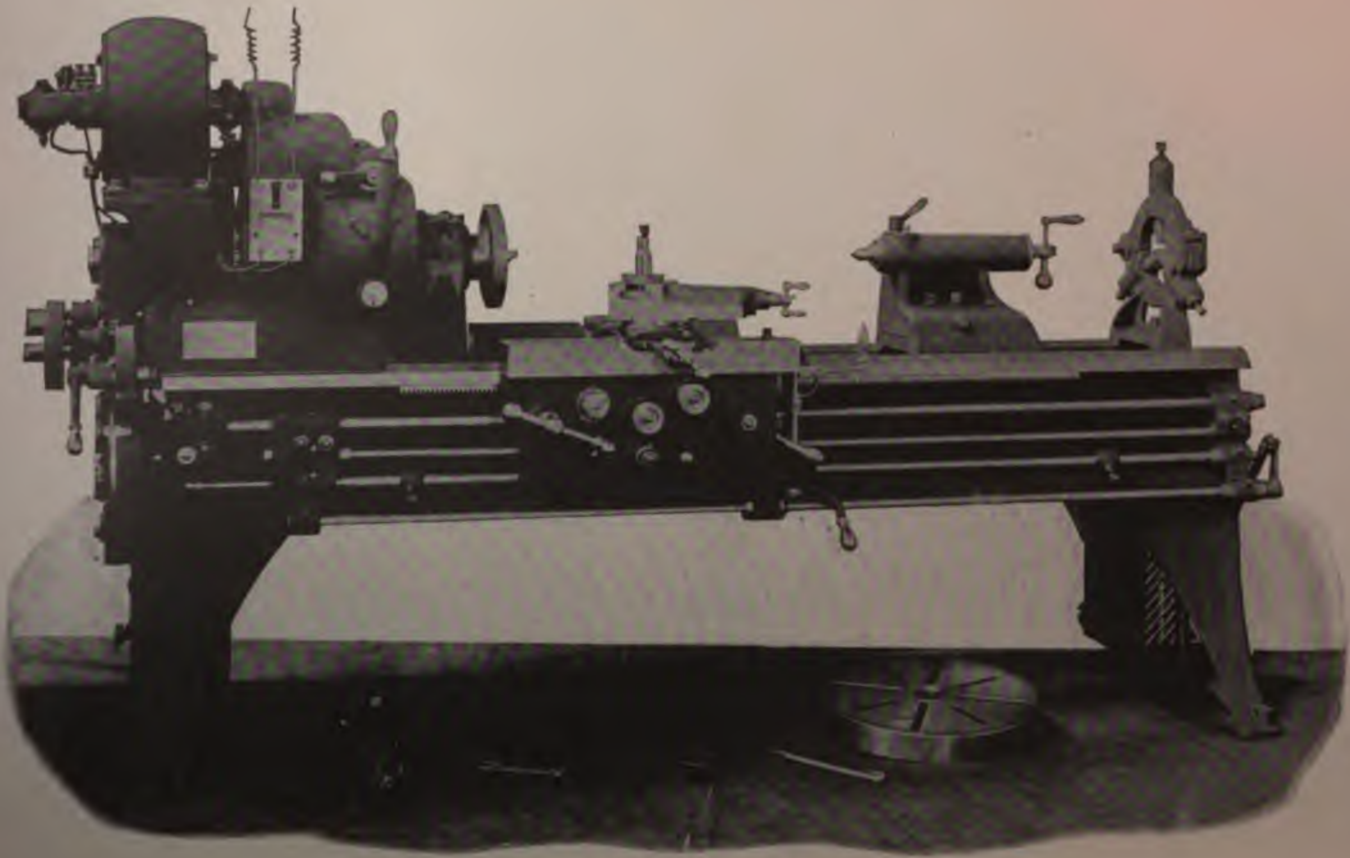

LATHE WITH SINGLE-VOLTAGE FIELD-WEAKENING MOTOR.

Controller Operated by a Handle on the Carriage.

ELECTRIC MOTORS IN MACHINE-SHOP SERVICE.*

I intend to consider the subject "electric motors in machine-shop service" from the standpoint of the shop engineer, whose one thought is economy in the broadest sense of the word. To such a man, the motor is but a single detail of the equipment—possibly one of the most important details, but only so when its relation to the problem as a whole, is understood. The development of alloy steels, permitting of cutting speeds from two to four times as great as was heretofore possible, requiring, in many instances, machines of new design; the introduction of the grinding machine, which is rapidly replacing the lathe for much finishing work; the milling machine; the electric motor as a means of driving; and types of management to assure efficient use of equipment, are among the most important factors requiring his attention.

The manufacturers of electrical apparatus too often defeat their own ends by overenthusiasm, or rather, by extravagant claims that they cannot possibly substantiate. There is no use trying to convince the shop engineer that the words "motive drive" are synonymous with "low cost," for he knows that efficiency attained depends upon the co-operation of a multitude of things, and primarily the intelligence with which the equipment is handled. If, however, the possibilities of the motor drive are properly presented, he can appreciate them better than any one else, for they fill a definite need, the importance of which he will understand.

It is not necessary to dwell upon substantial progress recently made in shop practice, which has resulted, in many instances, in greatly increased output with consequent reduction in cost. I shall consider rather what is needed to increase efficiency in the average shop, where it is still extremely low, for even when adequate funds are provided for the purchase of new equipment, the end in view is often defeated through lack of proper insight in connection with its purchases, installation, and use.

At the same time electrical manufacturers have not made the progress that would have been the case had they possessed a thorough understanding of shop requirements. Our experience has been confined largely to the installation and operation of electrical equipment under working conditions, therefore I shall treat the subject from this side, with the hope that I may bring more clearly before the manufacturers the conditions they must meet, and at the same time aid the customer in specifying his requirements and securing results.

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* This paper was presented before the International Electrical Congress of St. Louis, 1904, by Charles Day of the firm of Dodge & Day, Engineers, Philadelphia, Pa; and is reprinted by special permission.

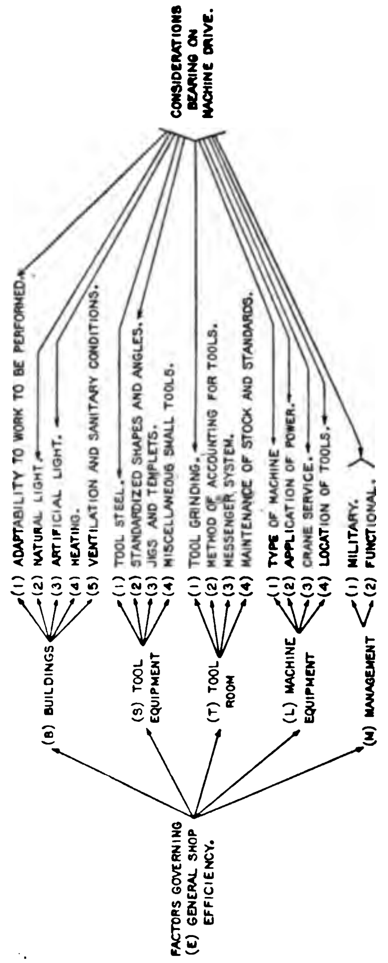
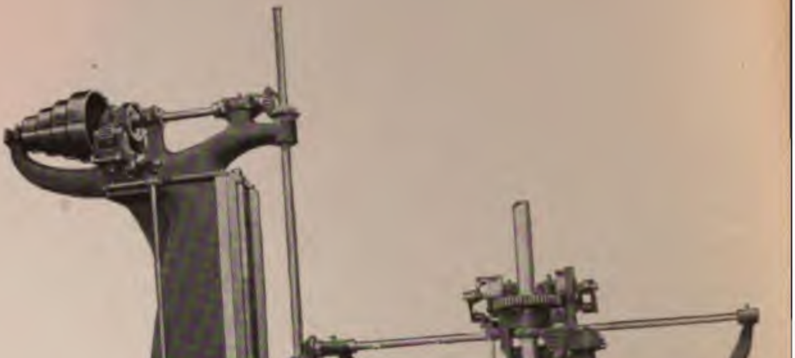

CONSIDERATIONS BEARING ON MACHINE DRIVE.
(1) ADAPTABILITY TO WORK TO BE PERFORMED.
(2) NATURAL LIGHT.
(3) ARTIFICIAL LIGHT.
(4) HEATING.
(5) VENTILATION AND SANITARY CONDITIONS.
(1) TOOL STEEL.
(2) STANDARDIZED SHAPES AND ANGLES.
(3) JIGS AND TEMPLETS.
(4) MISCELLANEOUS SMALL TOOLS.
(1) TOOL GRINDING.
(2) METHOD OF ACCOUNTING FOR TOOLS.
(3) MESSENGER SYSTEM.
(4) MAINTENANCE OF STOCK AND STANDARDS.
(1) TYPE OF MACHINE
(2) APPLICATION OF POWER.
(3) CRANE SERVICE.
(4) LOCATION OF TOOLS.
(1) MILITARY.
(2) FUNCTIONAL.
(B) BUILDINGS
(S) TOOL EQUIPMENT
(T) TOOL ROOM
(L) MACHINE EQUIPMENT
(M) MANAGEMENT
FACTORS GOVERNING (E) GENERAL SHOP EFFICIENCY.

Fig. 1.

Shop Considerations Bearing on Machine Drive.

Generally speaking, the electric motor (either for group driving or individual operation of machines) is conceded as the proper



EIGHT-FOOT ARM RADIAL DRILL.
Fosdick Mach. Tool Co.

means of power distribution. My paper will deal with the subjects under the following headings:

(1) Shop Requirements.
(2) Notes Concerning Motor-Drive Systems.
(3) Notes Concerning Different Makes of Apparatus.
(4) General Conclusions.

(1) SHOP REQUIREMENTS.

My paper will only permit of a general outline of shop considerations bearing on the subject; these are illustrated in Fig. 1. Each factor must be carefully considered and, when treating the subject generally, certain assumptions made. For example, we are justified in assuming that the best tool steel should be used and design accordingly, while crane service and type of workmen are, on the other hand, matters depending on class of work handled and local conditions.

An intimate knowledge of shop practice is quite as necessary to the designer of electrical apparatus for machine *driving* as to the builder of the machine, and, while frequently difficult to show the direct bearing of the various features of management and methods upon a single factor, such as the one under consideration, the most useful conclusions can be drawn only by those familiar with the subject in detail. Improved systems of management are doing much to assure proper use of equipment, but in any event the need of explanation in connection with its operation should be eliminated to as great a degree as is possible. In other words, apparatus should primarily be designed to give satisfactory results in the hands of average workers. Where its adjustment and manipulation is dependent upon the operator, he must be fully considered

---

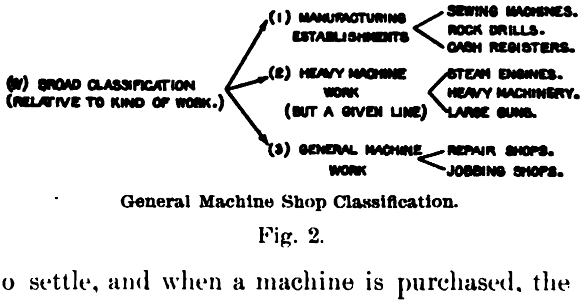
1. The words "machine" and "tool," as used in connection with machine-shop work, are very frequently ambiguous. I will use them in the following sense: *Machine.*—Definition (Standard Dictionary). Any combination of inanimate mechanism for *utilizing or applying power.* A construction for mechanical production or modification. Example—Lathes, pneumatic drills, power shears, etc. *Machine Tool.*—This term is often confusing and need not be used in present paper. *Tool.*—Definition (Standard Dictionary). A *hand instrument.* Not a mechanism. Used directly for production. Examples.—Chisel, hammer, saw, etc.

Tools for removing metals will be further subdivided as follows: Cutters, millers, drills, etc.

in the design, but when attention is required for inspection at intervals only, the personal equation does not enter into the problem to as great an extent. Lathe and elevator drives illustrate the two cases.

If cuts are of long duration, the cutting speed can readily be determined by experiment, but this is not practical in the run of machine-shop work. The determination of cutting speed for miscellaneous work is a difficult matter, and must be given special study in each case, every means toward uniformity of product being resorted to.

The drive is but a detail of the machine. We should aim at a harmonious whole, not combining an efficient drive with an out-of-date tool. The motor-driven tool of the future should not be considered a combination, but a *unit* suited to certain specific ends. The motor-drive problem is essentially a matter for the machine builder to settle, and when a machine is purchased, the customer should have the assurance *that the drive has been given the same care in design and construction as any other part of the machine, and need not be considered as a distinct issue.*



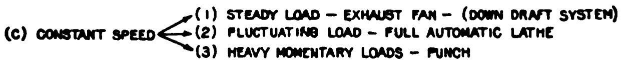
General Machine Shop Classification.

Fig. 2.

Machine shops may be broadly classified according to character of output as follows:

Shops of the first class can be laid out in every detail with regard to a definite need. Machines are purchased to do just one job, and frequently it pays to design special machinery for such duty. After it is properly adjusted for the character of material to be worked and for the cutters, no changes are required until better methods or facilities are developed. Here, as far as the drive is concerned, we find the simplest conditions. Usually constant speed with adequate power suits the case.

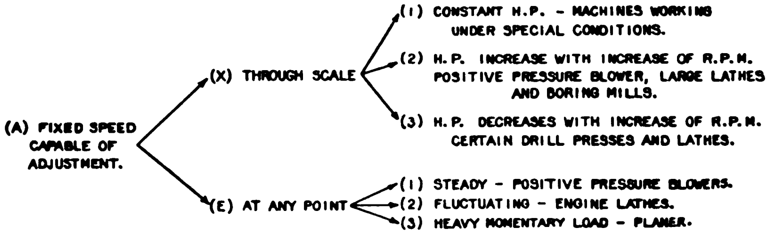
In shops classified under the second heading, little opportunity for duplication, in the sense just considered, exists. Machines must handle a variety of work, and even those purchased for specific operations are usually suited for other purposes so they may be kept busy the greater part of the time. Variation in size of work, material and cutters, demands an adjustable speed drive together with change feeds, if most economical results are desired. This is true to a still greater degree for machines in the third class.


(C) CONSTANT SPEED
(1) STEADY LOAD – EXHAUST FAN – (DOWN DRAFT SYSTEM)
(2) FLUCTUATING LOAD – FULL AUTOMATIC LATHE
(3) HEAVY MOMENTARY LOADS – PUNCH

Character of Load for Constant Speed Drive.

Fig. 3.

The drive requirements from a consideration of work to be performed can be further analyzed as shown below:


(A) FIXED SPEED CAPABLE OF ADJUSTMENT.
(X) THROUGH SCALE
(1) CONSTANT H.P. – MACHINES WORKING UNDER SPECIAL CONDITIONS.
(2) H.P. INCREASE WITH INCREASE OF R.P.M. POSITIVE PRESSURE BLOWER, LARGE LATHES AND BORING MILLS.
(3) H.P. DECREASES WITH INCREASE OF R.P.M. CERTAIN DRILL PRESSES AND LATHES.
(E) AT ANY POINT
(1) STEADY – POSITIVE PRESSURE BLOWERS.
(2) FLUCTUATING – ENGINE LATHES.
(3) HEAVY MOMENTARY LOAD – PLANER.

Character of Load for Adjustable Speed Drive.

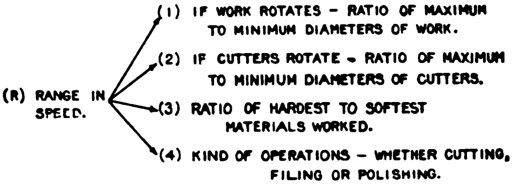
Fig. 4.

Figs. 3 and 4 relate to *character* of load. Figs. 5 and 6 are a further analysis of adjustable speed drive, for machines using cutters, giving details that should determine *range* and *number* of speeds.

Adjustable speed[2] may be desirable on grinding machines also, and in this case will depend on ratio of maximum to minimum wheel diameters and other matters that must be considered separately in individual cases.

[2] The words "variable speed" are now generally used for describing motors adapted for individual operation of machines, but to distinguish from the crane motor, for example, which is truly the variable-speed type, I shall use the words "adjustable speed" as describing a fixed speed capable of adjustment over a given range. Variable-speed motors are used principally for railway and crane service where the load is intermittent and torque variable. Direct-current apparatus has been developed to give such thoroughly satisfactory results for this duty that I shall not consider it other than in its relation to the general machine-shop problem.

Machines for punching and shearing, while usually arranged for constant speed, frequently require an adjustable-speed drive. For example, assume a punch operating at 28 strokes per minute. The operator may have work of such a character that he can easily punch a hole each stroke, while in another case, due to heavier sheets or greater accuracy required, he is compelled to skip every other stroke, punching but 14 holes a minute, while if the machine would permit he could readily do 28. Such a saving on this class of machinery usually yields a large actual return as the time required for setting up or making ready is, as a rule, small.

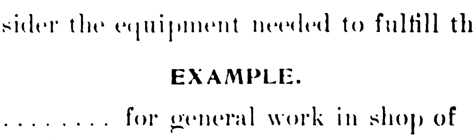

(R) RANGE IN SPEED.
(1) IF WORK ROTATES - RATIO OF MAXIMUM TO MINIMUM DIAMETERS OF WORK.
(2) IF CUTTERS ROTATE - RATIO OF MAXIMUM TO MINIMUM DIAMETERS OF CUTTERS.
(3) RATIO OF HARDEST TO SOFTEST MATERIALS WORKED.
(4) KIND OF OPERATIONS - WHETHER CUTTING, FILING OR POLISHING.

Factors That Influence Range of Speed.

Fig. 5.

The *amount* of horse-power required for machines of different types depends on the factors given in Fig. 7.

I have given the principal items to consider when designing or selecting machine drives, but to more fully explain the line of reasoning that should be followed, I shall assume definite conditions, and consider the equipment needed to fulfill them.


(N) NUMBER OF SPEEDS.
(1) UNIFORMITY OF MATERIAL WORKED.
(2) UNIFORMITY OF CUTTERS.
(3) NUMBER OF FEEDS PROVIDED.
(4) FACILITIES ENABLING WORKMAN TO DETERMINE PROPER SPEED.

Factors That Influence Number of Speeds.

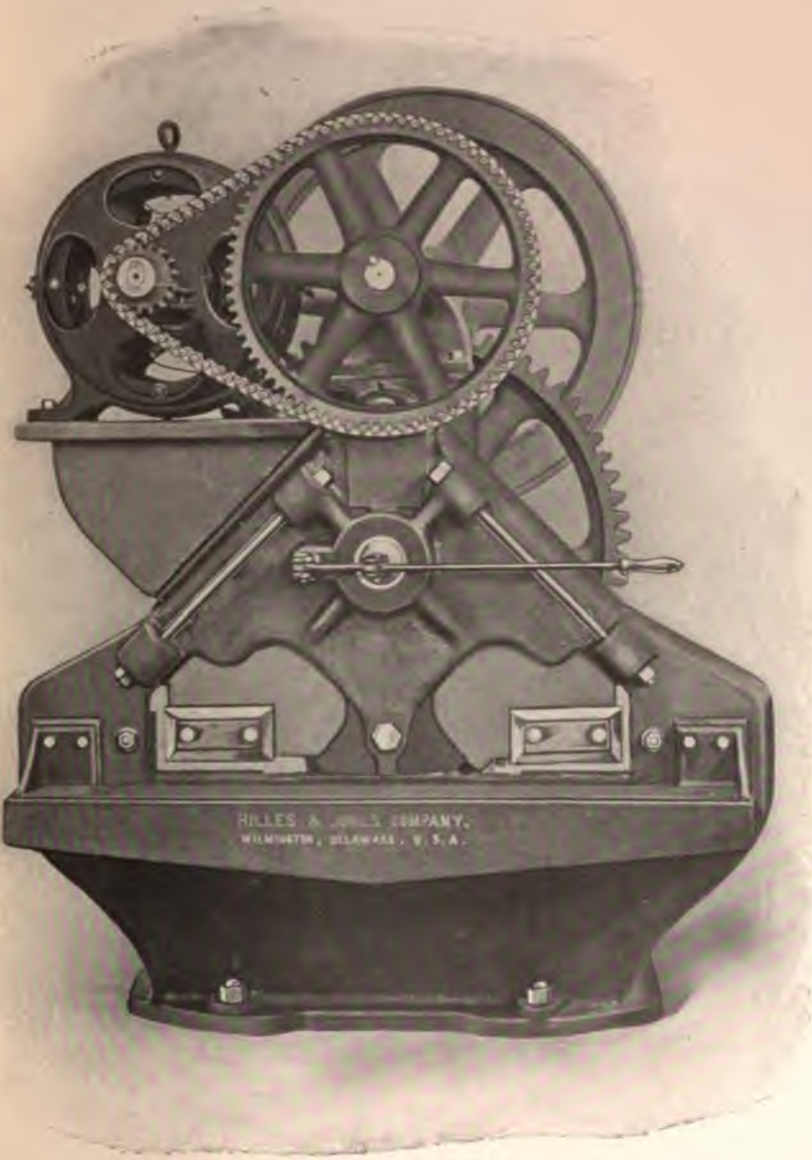
Fig. 6.

EXAMPLE.

LATHE........ for general work in shop of A. — — — —. B. — ——. Company, manufacturer of air compressors.

General features of this plant and its organization that influence type of drive (see Fig. 1).

E.B.—1. The machine under consideration is to run in an old plant, hence no saving in cost of buildings could be effected by type of drive.



MOTOR-DRIVEN SHEAR.

Morse Chain Company.

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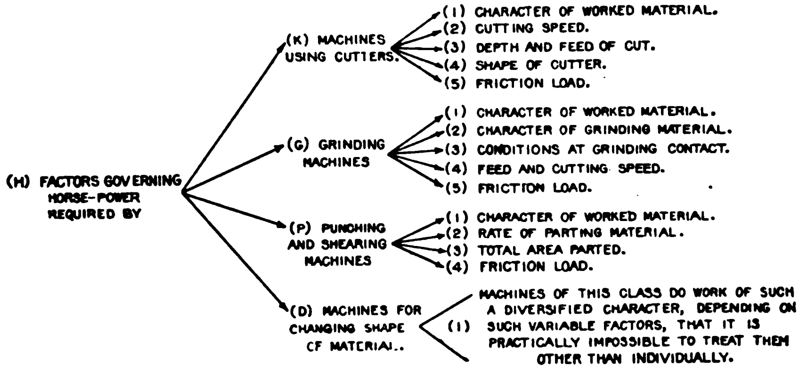
E. B.—2. The natural light at point where lathe is to be located is very poor, and it is important not to obstruct it any more than absolutely necessary.

E. B.—3. Artificial light has in the past been supplied by independent company, but they desire to install a power plant that will take care of this feature as well as power. It is desirable to depend largely upon general illumination by arc lamps with incandescent lights for detail work.

E. S.—1-2, and E. T.—1. For roughing work the best alloy steels, forged, treated, and maintained by special department, assuring uniformity and high efficiency, will be used.

E. L.—1, 2, 3, 4. Character of work necessitates constant use of power crane, making overhead belting and fixtures objectionable and difficult to provide for on account of location in main bay of shop. As cost of power in this plant amounts to less than 3 per cent of total cost of product, it is not a determining factor in character of drive.


(H) FACTORS GOVERNING HORSE-POWER REQUIRED BY
(K) MACHINES USING CUTTERS
(1) CHARACTER OF WORKED MATERIAL.
(2) CUTTING SPEED.
(3) DEPTH AND FEED OF CUT.
(4) SHAPE OF CUTTER.
(5) FRICTION LOAD.
(G) GRINDING MACHINES
(1) CHARACTER OF WORKED MATERIAL.
(2) CHARACTER OF GRINDING MATERIAL.
(3) CONDITIONS AT GRINDING CONTACT.
(4) FEED AND CUTTING SPEED.
(5) FRICTION LOAD.
(P) PUNCHING AND SHEARING MACHINES
(1) CHARACTER OF WORKED MATERIAL.
(2) RATE OF PARTING MATERIAL.
(3) TOTAL AREA PARTED.
(4) FRICTION LOAD.
(D) MACHINES FOR CHANGING SHAPE OF MATERIAL.
(1) MACHINES OF THIS CLASS DO WORK OF SUCH A DIVERSIFIED CHARACTER, DEPENDING ON SUCH VARIABLE FACTORS, THAT IT IS PRACTICALLY IMPOSSIBLE TO TREAT THEM OTHER THAN INDIVIDUALLY.

Factors Governing Horse-Power Required for Different Types of Machines.

Fig. 7.

E. M.—2. The type of management being introduced at this plant should ultimately assure intelligent direction of work and proper use of equipment.

Referring to Fig. 2:

We find that this shop will come under the class indicated by the symbol *W-2.*

Referring to Fig. 4:

(A)—X—1—F—2. Majority of work (probably 80 per cent) will be steel and gray-iron castings between 18 ins. and 48 ins. diameter. Maximum conditions call for removal of same amount of metal between these limits, and approximately constant cutting speed. Maximum horse-power requirements are consequently constant through the range, but subject to fluctuations at any one point below the said maximum.

ring to Fig. 5:

At times it will be necessary to machine work as small as 10 ter, or as large as 60 ins. diameter; consequently a range in d 1 would be required for this purpose.

R Cutters will always be stationary.

R— The ratio of hardest to softest material required by specifica- n be approximately 2:1. This will increase the necessary speed range 0:1.

4. The majority of work will be roughing and finishing with e Some filing and finishing with emery cloth will, however, be n y, and for this purpose experience would dictate a cutting speed per minute on 10 ins. diameter It will be necessary to provide g speed of 15 ft. per minute on the largest diameter on account of ail character and difficulty of driving some of the castings to be ma- ed. Total range of speed is determined by limiting conditions of a ing speed of 15 ft. per minute on 60-in. work and 150 ft. per minute on in. work. I have purposely chosen these extreme conditions to better ustrate my point. In practice a 60-in. lathe is seldom required to run 57 r.p.m.

$$\frac{150}{\frac{10 \times 3.14}{12}} = 57.3 \quad \text{r.p.m.}$$

$$\frac{15}{\frac{60 \times 3.14}{12}} = \quad .95 \text{ r.p.m.}$$

Consequently, for all practical purposes, the face plate of the lathe should run from one revolution per minute to 57 revolutions per minute.

Referring to Fig. 6:

N—1. It was stated above that the character of material would vary in the proportion of 2 : 1, this being a requirement of the products manufactured. Uniformity of material, or how nearly the requirements can be attained under shop conditions, is one of the factors influencing the number of face-plate speeds.

A fully-equipped laboratory, under the direction of an able chemist, who has entire charge of the cupolas and Bessemer steel converters, assures a much more uniform product in the plant in question than is usually the case. A great deal of experiment and investigation will be necessary however, before we can make definite assertions in this direction, but castings from the same pattern should not vary more than 20 per cent.

N—2. Cutter of the character indicated above (E.S.—1) should not vary in efficiency more than 10 per cent.

N—3. The full consideration of this point involves an understanding of the laws governing speed, feed, and cut for various materials. It will not be practical to include here full data on this detail. **Hundreds of** tons of steel and cast iron have been cut up to determine these relations, and constant experiment is necessary to keep abreast of rapid improvements. I will only say that it is quite as necessary to provide an adequate number of feeds as it is spindle-speeds, and in fact a limited number of either one of these factors will give efficient results provided a very close regulation can be had on the other.

In the present instance it was not considered advisable to specify changes to the standard feeding mechanism, as this feature had been well taken care of by the builder.

N—4. As the operation of the machine is ultimately governed by the facilities at the disposal of the machinist who runs it, it is absolutely essential that this point be given most careful study. It involves practically every feature of shop system and management, and it is only under such systems as that developed by Mr. Fred W. Taylor, of which functional foremanship is but a single detail, that the conditions, as outlined above, can be fulfilled. It necessitates that the operator of the machine be informed as to the character of the material, efficiency of the cutter, proper cutting speed in consideration of duration of cut, and many other equally important factors.

So it will be seen that we cannot arrive at any data which would enable us to specify definitely the number of spindle-speeds required. Our conclusions must necessarily be based principally on experience in shop practice, and for this reason engineers differ widely in their views. For the example under consideration, speeds increasing in increments of 15 per cent are, in our estimation, quite as close as can be used to advantage. It is well, however, to err on the safe side, providing too many speeds rather than too few.

Referring to Fig. 7:

H. K.—1, 2, 3, 4. Maximum permissible cutting speed on steel castings will be 60 ft. per minute; on gray-iron castings 60 ft. per minute (determined by actual requirements on a large variety of work). Maximum cut, cast-steel, 3/8 in. deep, 1/16 in. feed; gray-iron, 3/8 in. deep, 1/16 in. feed. (These conditions are established by character of work.)

The experiments conducted to determine the laws governing speed, feed, and depth of cut, for various materials referred to above (N—3), have been made available for purposes of design by means of slide rules, based on the derived empirical formulæ.

For the depth of cut and feed under consideration (cast steel), the calculated pressure on the tool would be: 5,550, or horse-power required

$$\frac{5550 \times 60}{33,000} = 10.1 \text{ hp.}$$

H. K.—5. The friction load can only be arrived at through experience and depends not only on the machine, but character and method of doing work. Experimental data on machines quite similar to the one under consideration would indicate 2 horse-power through the entire range as sufficient to allow for this purpose.

These conditions are plotted in Fig. 8. It will be noticed that the horse-power falls off on either side of the working part of the range

While it is easy to theorize as to the horse-power required for work of various diameters, in actual practice the conditions are about as I have shown. It must be borne in mind that the machine under consideration should be primarily adapted for the majority of work that it will handle. We have assumed that 80 per cent of this will be between 18 ins. and 48 ins. in diameter, so that work outside of these limits is the exception. On small work, such as would be handled, there is not likely to be opportunity for as heavy roughing cuts, and castings over 48 ins. in diameter cannot be swung over the carriage, nor would it be good policy to aim at high efficiency at this point for the additional cost would not be justified by the saving effected on such a small fraction of the total output.

As the horse-power between the working limits shown above was figured for the maximum cutting speed of 60 ft. per minute, we can plot a relation between revolutions per minute and horse-power. (See Fig. 9.) The selection of electrical equipment for this lathe will be taken up further on.

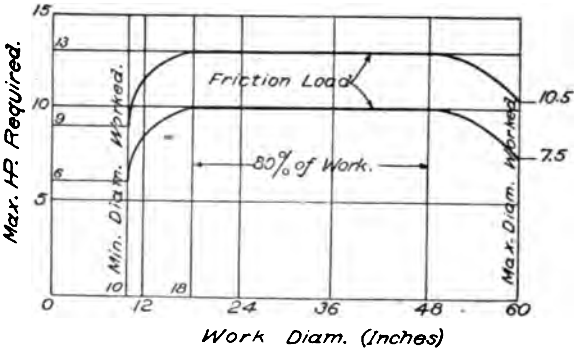


Fig. 8.

The analysis of conditions presented above is, as was stated, essentially a problem for the machine builder to work out—in other words, the electrical companies should look to him for general specifications covering motors and controllers.

When equipping machines of old design with motor drive, or remodeling them to better their efficiency, each one should be considered separately with regard to the special line of work it handles. As manufacturing becomes more specialized it will be possible for the builder of machines to design with more intelligence, for he can then treat a type as we have treated an individual.

To avoid repetition, I will assume the following conclusions have been established.

(1) Machines of present design of comparatively small work, requiring constant-speed drive should, in most instances, be grouped

and operated from motor-driven line shafts. Specifications for new machines for such duty should be made with a view to special requirements. Indirect savings in one plant may much more than offset additional cost of constant-speed motor on each machine, while this would not be true in another.

(2) For group driving, both direct- and alternating-current motors give thoroughly satisfactory results. In either instance, if properly installed, repairs should not be an important feature. In certain industries—the textile mills for example the induction motor has decided advantages on account of close-speed regulation with varying loads and lessened fire risk, but for machine shops these features are unimportant.

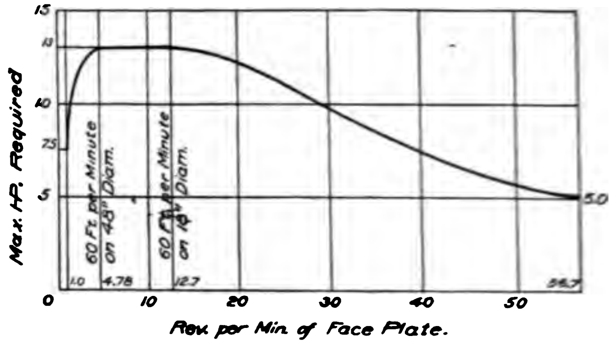


Fig. 9.

(3) Mechanical means of speed control, including step cone pulley and variable-speed countershafts, while suited for certain specific cases, do not meet the general requirements of machine drive. An attempt to obtain the necessary speeds by gearing, for example, is not only costly (if a sufficient number of changes are provided), but inefficient, in that as a rule, the machinery must be stopped to change from one speed to another, and cannot be controlled from an independent point.

(4) For adjustable speed work, direct-current motors only give satisfactory results at the present time. It is not practical by this means to use a range greater than 6 to 1, while in the majority of cases 3 to 1 gives the most economical results. In other words, in most instances, it is necessary to resort to a combination of mechanical and electrical control, the disadvantages of

each being largely eliminated by this means. For example, even where machines are handling a very general line of work, the greater part of it will be covered by a range of 3 to 1, so that if this amount is obtained electrically, gear changes will be seldom necessary, and at the same time a comparatively inexpensive motor required. Consequently the lathe requirements specified above are of quite as much value to the man who designs the mechanical features of the machine as the one who furnishes the electrical apparatus.

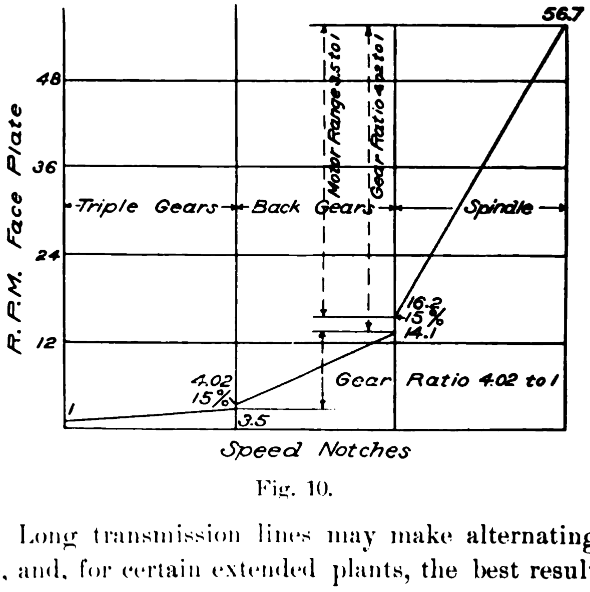
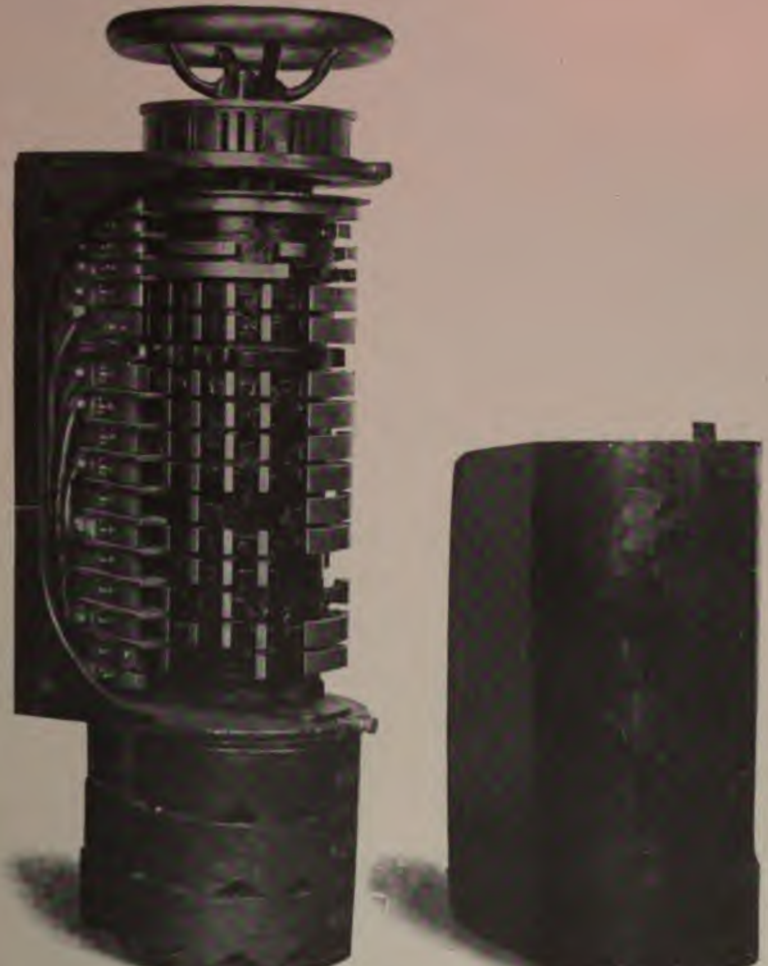


Fig. 10.

(5) Long transmission lines may make alternating-current desirable, and, for certain extended plants, the best results can be obtained by its use, together with motor-generator for direct-current variable-speed motors. If, however, but one kind of current will be available, decision should be largely governed by number of individual drives required. In many instances, while group drives may be desirable at the start, new equipment should be purchased with individual motors for the sake of adjustable speed and ease of control.

Returning to the 60-in. lathe considered above, the total speed range of 57 to 1 can be covered by the usual triple gear arrangement, with the resulting ratios shown on the chart. The range in motor speed, of 3.5 to 1, is quite practical and can be taken care of by any one of the systems referred to above.



MULTIPLE-VOLTAGE CONTROLLER.

Crocker-Wheeler Company.

I shall not dwell upon the strictly mechanical details of the drive, rather assuming that this part of the work is properly taken care of, but pass on to a consideration of the motor-drive systems.

(2) NOTES ON MOTOR-DRIVE SYSTEMS.

Systems now on the market for obtaining adjustable speed by means of motor drive, and advocated by prominent manufacturers, are given below:

(1) Field weakening only

(2) Double commutator motor combined with field weakening.

(3) Edison three-wire system combined with field weakening.

(4) Unbalanced three-wire system combined with field weakening.

(5) Four-wire multiple-voltage system combined with field weakening.

There are two classes of purchasers, with widely differing requirements, and to whom different systems appeal:

(1) The customer who buys motors for his own use to equip machines already in operation, or special machinery which must be given individual consideration.

(2) The customer who buys for an unknown third party. The builder of machines, for example, who manufactures his product without any knowledge as to whom the purchaser may be, and consequently must design equipments that will meet conditions existing in plants where his product is solicited.

The electrical manufacturers have been slow in realizing this almost self-evident classification. The very essence of modern manufacturing consists in specialization, as it is only in this way that cost can be reduced to a minimum. Such establishments must be classified under the second division referred to above, and the product considered as a *type*, while in the first class given machines or given establishments can be treated separately.

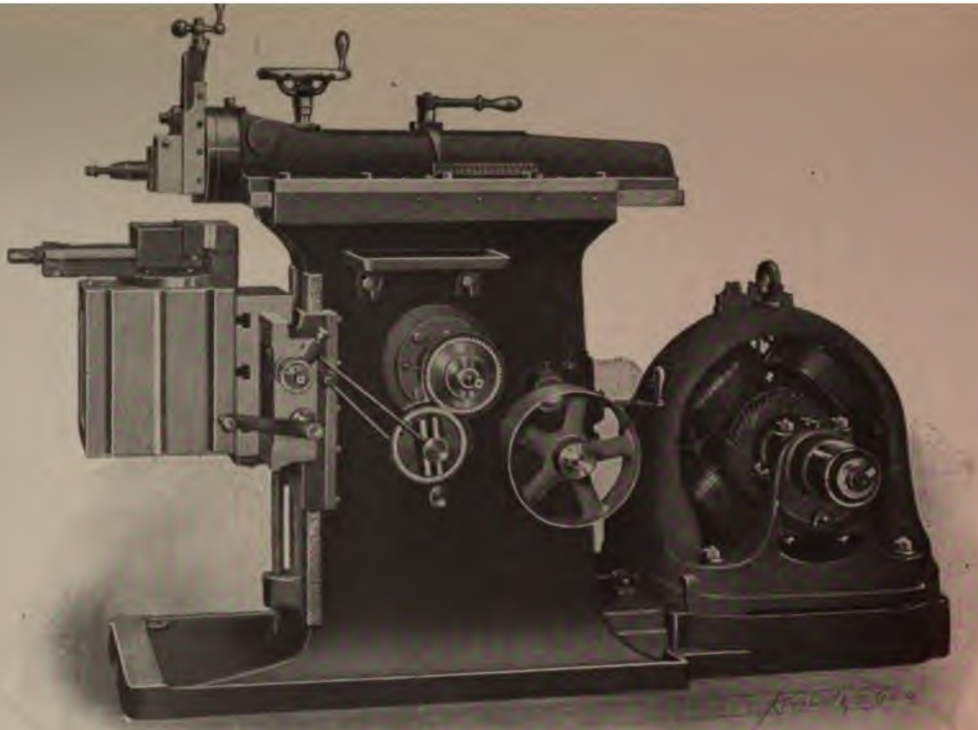
Conditions in the past have in either case demanded a separate consideration of drive for practically every customer, on account of special character and numerous types of motor-drive equipment, but substantial progress, as far as the machine builders are con-
will not be made until their product is manufactured com-
y essential. This means the adoption of a motor that

can be operated on 110 or 220 volts, direct current, as one of these is not only found in nearly every large establishment, where it is used for cranes and lighting, but in many of the small shops.

The three- and four-wire systems, on the other hand, have been installed by a very small percentage of the shops who are, from time to time, purchasing new equipments, hence for commercial reasons such apparatus does not appeal to machine builders. It may, however, possess distinct advantages to purchasers of the first class who contemplate the motor equipment of an entire shop, either at once or as conditions demand. As they can exercise the greatest freedom in selection of equipment for motor drive, I shall consider the systems enumerated above from their standpoint. It will then be a comparatively simple matter to apply these conclusions to the more special conditions which must be met by the machine builders.

All customers, unless they employ consulting engineers, are called upon to decide themselves upon the system to adopt, and, as their experience does not, as a rule, cover the details of electrical engineering, they must depend largely on the statements put forward by electrical companies.

There is no doubt that the manufacturers in many instances have taken advantage of the special character of machine work to rate their motors in a way that is very deceptive. The words "full load" are almost universally abused, and as there is no standard specification adhered to, the only safe basis for comparison is through a knowledge of the weight and maximum speed for a given horse-power through a given range, with the understanding that a specified overload must be carried at any point for a certain time. Such an analysis would, according to the views of the various builders, give at least an intelligent idea of the equipment required to fill a definite need, but in a number of instances our experience has indicated that claims made by leading manufacturers have not been fulfilled in actual test. Machine-tool duty unquestionably permits of a different basis of rating from constant horse-power work in much the same way that street railway motors are rated on a basis of their own, but when one manufacturer adheres strictly to a rating of present standard, and another departs from it without the knowledge of the customer, the latter is likely



CRANK SHAPER. DRIVEN BY VARIABLE SPEED MOTOR.
Cincinnati Shaper Co.

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TILDEN FOUNDATIONS

to be comparing bids on two radically different equipments. This we have repeatedly found to be the case. We feel that this matter should be given careful consideration by such a body as the American Institute of Electrical Engineers and a definite understanding arrived at.

I shall assume general familiarity with the systems under consideration. In general, a motor for a given maximum speed and a given range, to deliver a given horse-power through this range, will be at least as large when operated by field weakening only, as when a combination of either two or more voltages with field weakening is adopted. Unless the motor is specially designed for field weakening, it will be larger than in the latter case. We have been unable to obtain any satisfactory data from the engineering departments of electrical manufacturers concerning variation of horse-power with field strength, so prefer to base our conclusions upon tests which we have conducted in connection with work for various clients.

As the cost of variable-speed motors and auxiliary power transmission equipment, such as chain or gears, is in proportion to the speed at which it operates, we should see that the latter is as high as is consistent with the various engineering considerations. A number of the manufacturers of motors do not give sufficient thought to the adaptation of motor speeds to available means of transmitting power to the machine. There are three methods in common use, namely: leather belts, gears (including worm and spiral gearing) and chain. While the great flexibility of the belt, in relieving the machine of sudden jar, has distinct advantages in certain instances, gears and chain are used in the majority of cases for individual drive.

(1) FIELD WEAKENING (WITH A SINGLE VOLTAGE).

A number of manufacturers have recently placed on the market motors designed to run on a single voltage, but that may be varied in speed by means of field weakening over a range, in some cases, as high as 6 to 1. Until recently, ranges as great as the above have not been considered practicable and our tests of motors of various makes have indicated that in this respect much can be accomplished through careful motor design. Manufacturers that adhere to the simple shunt type do not advocate, except for special work, a range exceeding 4 to 1, while others who have adopted either additional poles or special windings claim to have eliminated the difficulties usually encountered, and are prepared to furnish motors giving any variation desired. These types, however, have not been in operation a sufficient length of time to enable us to confirm their statements.

We have found that customers are frequently misled concerning the size of frame required for a given duty for motors operating on this system. As the horse-power that can be developed with a given frame is in proportion to the speed of the armature, it is necessary to use, for a range of 4 to 1, a motor frame rated at least four times as large as the power required if practical speeds are not to be exceeded. Even such a frame will not, in most cases, make it possible to rate the motor as liberally as is the case with standard constant-speed apparatus, as the exceptionally strong field required is likely to cause heating at the slow speed, and at the high speed the weakened field will cause poor commutation.

We have not yet experimented with a motor of this type that would operate continuously under the full-load current at its highest speed without giving some trouble at the commutator. It is true, as was stated above, that such conditions would rarely be met in the machine shop, but to purchase with intelligence it is necessary to know how much manufacturers depend on this fact. Motors with a range of 3 to 1 have already been successfully applied to machines requiring a comparatively small amount of power, although, as will be pointed out later, the apparatus has not been perfected as fully as is the case with other systems.

If the lathe considered above be equipped with apparatus operating on this system, the relation between motor horse-power and that required by the machine, shown in Fig. 11, should fulfill the conditions satisfactorily, as the upper curve is drawn through maximum values, and when they are reached the overload on the motor would only be 30 per cent.

Referring to the dimensions and ratings furnished by one of the manufacturers, whose apparatus has shown up very favorably under test, we find that a motor weighing 1,615 lbs. will deliver 10 horse-power between a range of 350 r.p.m. and 1,050 r.p.m., or one weighing 2,300 lbs. will deliver 10 horse-power between 225 r.p.m. and 900 r.p.m. We recommend the use of the last frame, as satisfactory commutation should be assured by the smaller speed range, namely, 225 r.p.m. to 787 r.p.m.

(2) DOUBLE COMMUTATOR MOTOR (COMBINED WITH FIELD WEAKENING).

The additional cost of the double commutator motor, together with the maintenance of two commutators instead of one, are objections to this system that, in our estimation, offset its advantages for other than special cases.

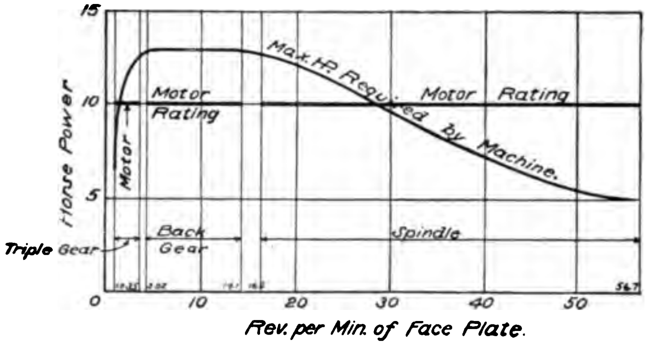

Fig. 11.

(3) EDISON THREE-WIRE SYSTEM.

The combination of the Edison three-wire system with field weakening permits of a range of 4 to 1, with but 100 per cent increase in speed by the latter means, and, consequently, eliminates commutator troubles to a marked extent.

The balanced three-wire system has been adopted quite generally in the past for lighting purposes, and may be obtained either by means of standard generator, together with a separate balancer, or by providing the former with slip rings connected to an autotransformer from the middle point of which the neutral is taken. The latter arrangement is advocated by manufacturers of this apparatus.

The selection of motor to operate on three-wire system for the 60-in. lathe should be based on curves shown in Fig. 12. The same assumptions are made regarding overload as in the former case.

The motor required for these conditions, according to one of the principal advocates of the Edison three-wire system, would weigh 2,600 lbs. and operate from 220 r.p.m. to 880 r.p.m.

(4) THE UNBALANCED THREE-WIRE SYSTEM.

The unbalanced three-wire system was developed to give, with a minimum size motor, a range somewhat greater than 6 to 1.

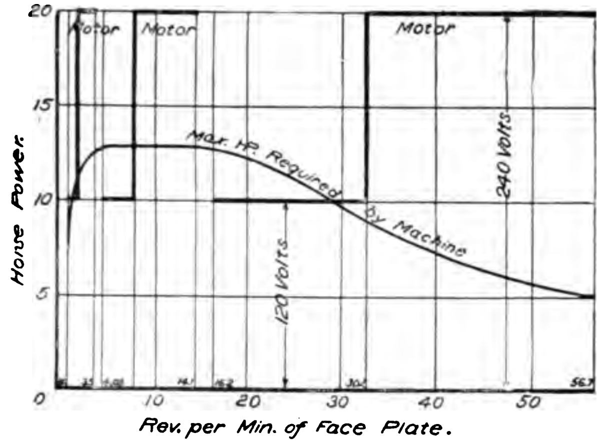

Fig. 12.

For a range of 4 to 1, or under, it has no advantage over the balanced three-wire system, nor does it possess the several good features of the one last named.

(5) FOUR-WIRE MULTIPLE VOLTAGE SYSTEMS.

The principal advantage of the multiple-voltage system is that absolutely standard motors (the same as are used for constant-speed duty) are used with perfectly satisfactory results. This is not true of any of the other systems. Motors designed to operate on a three-wire system must run with full field, full voltage at about half the speed of a constant-speed motor for the same duty, therefore cannot be economically used for the latter purpose. This is true to a still greater degree for motors designed to give a wide range of speed by means of field weakening only.

The maximum range in speed obtainable by the system under consideration depends upon the voltages adopted and the amount the field is weakened, but for purposes of economy, except where constant torque is required, the working scale is usually confined to the higher voltages. The lower voltages, while used chiefly for starting, prove of great assistance at times for setting up work.

The two systems which have been advocated differ in that one requires an arithmetical series of voltages, and the other a geometrical series. In either case a balancer, or specially designed generator, is required to give the voltage referred to and four wires employed for distribution. These two features are frequently cited as disadvantages that more than offset the good points of this system, but, in reality, they do not complicate matters to any great extent nor add materially to the cost of a large installation.

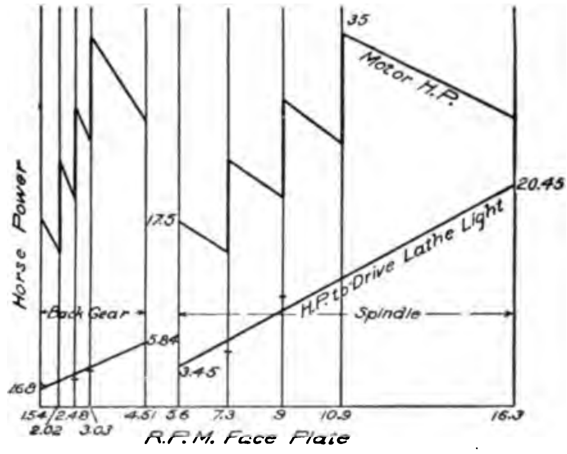

Fig. 13.

While, as stated above, the average machine tool may be considered as requiring constant horse-power through its working range, in numerous instances, particularly when dealing with large machinery, we find that requirements call for an increased horse-power with an increased speed. For such cases the multiple-voltage system is most desirable as is clearly shown by the curves in Fig. 13.

This data relates to a large gun lathe, driven by multiple-voltage apparatus. The lower curves are drawn through points determined by actual test and show the power required to drive the lathe with face plate in place, but otherwise running light. The power available for useful work is represented by the vertical height between the curves just referred to and the upper ones, which show the relation between horse-power and speed of a standard 35-horse power Crocker-Wheeler motor. Such examples are, of course, exceptional.

Thus far, I have assumed the use of the same range in motor speeds, when operating on the spindle, backgear, and triple gear, and in the case of field weakening motors, or those operating on a balanced three-wire system and rated as above there would not be any advantage in doing otherwise. The characteristics of the multiple-voltage system, however, are such that a smaller motor can frequently be used. The gear ratios are determined by the nature of the load curve. This fact was borne in mind when plotting the curves shown in Fig. 14 relative to multiple-voltage equipment for lathe A. B. Company.

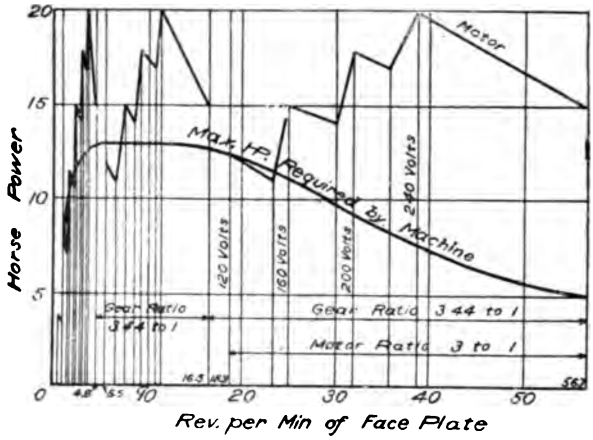

Fig. 14.

A motor weighing 2,350 lbs. and operating from 236 r.p.m. to 820 r.p.m. is recommended by one of the leading manufacturers of this apparatus. They prefer to rate their motors very conservatively, which accounts for the decrease in horse-power with field weakening. By actual test their motors stand up under these conditions as well as many other makes that are said to deliver constant horse-power through a range of 2 to 1.

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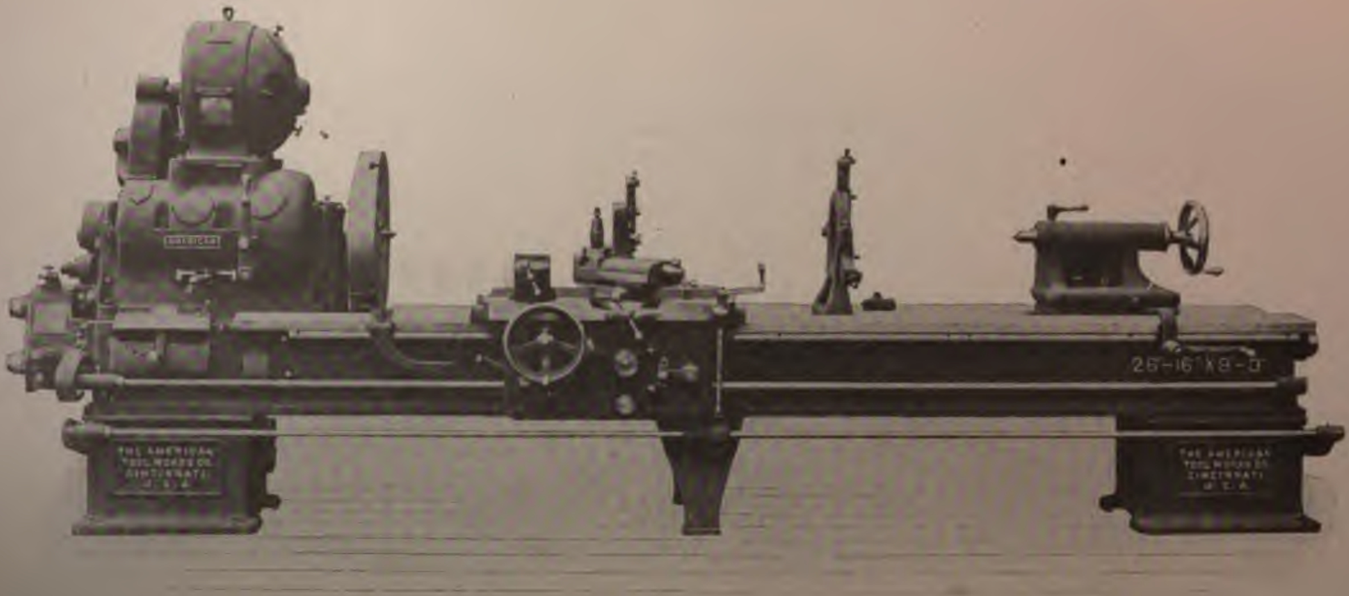
AMERICAN
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THE AMERICAN TOOL WORKS CO. CINCINNATI U.S.A.

LATHE EQUIPPED WITH CROCKER-WHEELER MULTIPLE-VOLTAGE APPARATUS.

Controller Arranged so that the Operator Can Start, Stop, and Obtain Any Spindle Speed Within Range of Motor, without Leaving His Work.

(3) NOTES CONCERNING DIFFERENT MAKES OF APPARATUS.

In every instance final decision must rest with the perfection of apparatus. One of the most important details so far as efficient shop use of the motor drive is concerned is the controlling mechanism. For machine-shop duty thoroughly rugged and compact controllers are required. No contacts should be exposed as is now the case with the apparatus furnished by a number of manufacturers of field weakening motors. With thoroughly efficient apparatus it is practically impossible to damage either the motor or controller by the rapid operation of the latter. I do not mean by this that it is well to swing the controller handle suddenly from the off position to the full-speed point, but such action should not result in destructive sparking at the commutator or arcing at the controller points.

The satisfactory operation of a controller for the conditions under consideration depends largely upon the success with which the manufacturer has fulfilled the following conditions:

(1) Controllers should be completely inclosed in iron casing.

(2) It should be impossible through the manipulation of the controller to stop the motor at any place on the scale other than the off position.

(3) Rapid operation of the controller should not cause serious damage to either motor or controller.

(4) They should be so designed that they can be easily operated from a convenient point on machine.

(5) A sufficient number of speeds should be provided, depending on machine requirements.

(6) Controllers that require frequent operation must be designed with liberal contact surface and more rugged in every respect than those used principally as "speed setters," and as a result only operated at intervals.

(7) The design should permit of repairs with the greatest ease. In this connection the location and type of resistance grids should be given careful consideration.

(8) Each speed should be clearly defined either by a star-wheel and pawl or other means.

A number of manufacturers have placed on the market controllers that are giving good results, and in most respects comply with the above requirements.

Motors have been designed to accompany these controllers that are well suited for application to machines, in so far as their external dimensions are concerned, but at the same time we feel sure that the electrical manufacturers who are willing in certain cases to depart from present designs will gain a strong position with the machine builders.

(4) CONCLUSIONS.

In all probability a paper such as I have prepared for this meeting of electrical engineers, would have seemed decidedly out of place some years ago. I have dealt with matters which would then have been considered the business of the machine builder or mechanical engineer, and not requiring the thought and study of the electrical profession. It is now realized, however, that the motor-drive problem presents many new features, and is a distinctly different one from the manufacture and sale of standard generators, for example. The earning power of the latter is largely dependent upon the design and workmanship, features that can be passed upon before the machinery leaves the works. If a power plant is found to be too small, more units can be readily added without in any way interfering with those in use. On the other hand the earning power of a motor equipment for individual operation of machines depends largely on conditions over which the manufacturer has no control. The continued growth of this department of his plant, however, is governed by results actually obtained with his product under working conditions, so to protect himself he is called upon to see that the proper equipment is selected, and if possible, advise as to its use. As far as the customer is concerned, it would usually be better for him to close his eyes and grasp any one of possibly four makes of apparatus, devoting his time to its proper installation and operation, rather than reversing the process as is so often done.

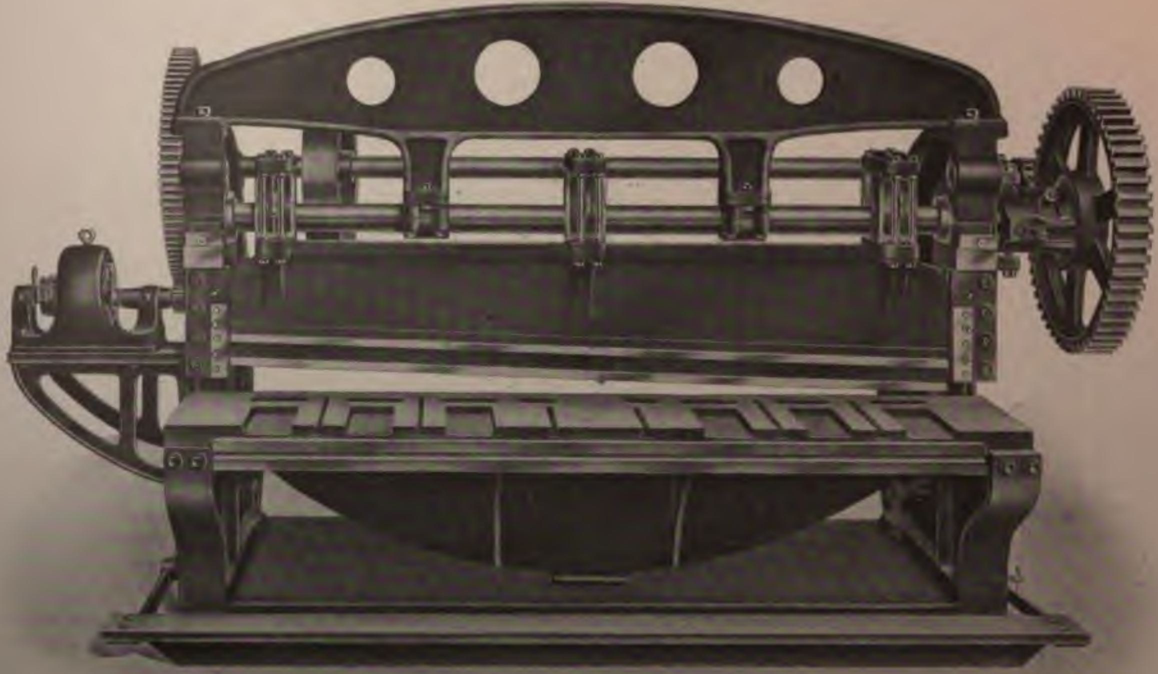
The conclusions reached above concerning the motors required for the 60-in. lathe are summarized in the table below:

	Weight.	Min. R.P.M.	Max. R.P.M.
Field weakening	2,300	225	787
Three-wire system	2,600	220	770
Four-wire system	2,350	235	820

It must be remembered that the ability of these motors to fill the imposed conditions was not determined by actual test, the data being the recommendations of well-known electrical companies who manufacture the respective types of apparatus. These figures should at least make it clear that many statements constantly made concerning the size of motor required for a given horse-power and speed range cannot be other than erroneous.

I pointed out above the conditions which must be met by the machine builder necessitating the selection of a type that does not require for its operation special auxiliary apparatus. While motors operating on two wires and giving a range as high as 4 to 1 by means of field weakening do not at present give as good all-round results as those operating on the multiple-voltage and three-wire systems, we feel that their adoption by the manufacturers referred to is certainly justified. When this is more fully appreciated the electrical companies should rapidly achieve better results in this direction.

The customer purchasing for his own use should, on the other hand, *differentiate clearly between the machine builders' requirements and his own*, for in many cases he can secure more satisfactory results, all things considered, through the adoption of a system combining with field weakening a number of voltages.



GUILLOTINE SHEARS. MOTOR DRIVEN.

Erie Foundry Company.

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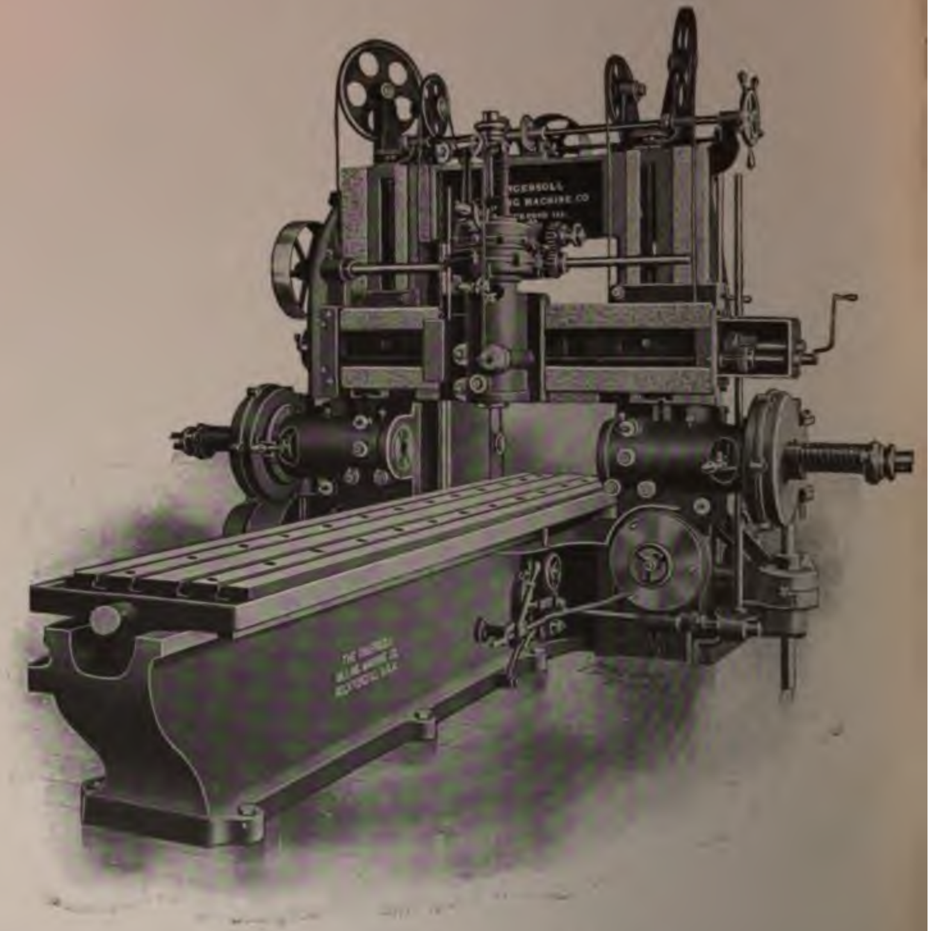


36" x 36" THREE HEAD MILLING MACHINE.
Ingersoll Milling Machine Co.

FLAWS IN CASTINGS

Thermite, which is mainly a mixture of finely divided aluminum and iron oxide, is known to go on burning spontaneously after it has been ignited at any point. This fact has been utilized by Dr. Goldschmidt in connection with a number of further discoveries and inventions constituting the body of quite a novel branch of chemical science to which the name *Alumino-thèrmics* has been given. In its spontaneous combustion, thermite produces temperatures as high as about 3,000° C. The iron is thus liberated in a pure state, free from carbon, a slag of aluminum oxide (the so-called artificial corundum) being formed at the same time. The use of thermite for obtaining castings free from pores and flaws is based on the fact that the material is able to burn without requiring any supply of gases, and without giving rise to the formation of any gaseous products in the reaction.

The action of thermite on metallic baths is a triple one:—In the first place, the metals produced by the reaction are alloyed to the bath; second, the heat of reaction of the thermite is transmitted to the bath; and third, in the case of a suitable application, a lively intermixing of the metallic bath will take place. The thermite is introduced into the liquid metal in a sheet-metal box, so as to produce the reaction below the surface of the fused metal. In the case of cast iron, titanium thermite is used, which is a thermite containing, in addition to aluminium and iron oxide, some titanium oxide intended to supply to the fused metal a certain amount of titanium, when any one of the three effects pointed out above will be produced.

A box filled with titanium thermite (Fig. 1) is fixed by a wire to an iron bar, the latter being fitted into a centrical hole in the box. The bar used in this connection should be fairly free from rust and perfectly dry. After the box and the bar have been reheated to the temperature of the hand, they are thrown into the metallic bath by a workman whose hands are protected by gloves against the radiating heat from the surface of the fused metal. During the reaction, the bar is kept within the metal as motionless as possible. After the thermite box has been dipped into the bath, the reaction will take place instantaneously, lasting about 1 to 1½ minutes in regular course; it is manifested externally by a lively bubbling of the bath, resulting in a mixture so intimate that it would be impossible by the use of any other agent. This intermixing is, of course, attended with a material improvement of the iron itself, any differences due to the variations in the iron from different stages melted together being compensated for. The iron expert will notice at once in the liquid metal, the influence exerted on its condition by the thermite reaction. In fact, the jet flowing from the cupola furnace onto a pan is perfectly opaque; while in the case of the iron undergoing the thermite reaction, the jet issuing from the pan has a clear, translucid appearance. The effect may be noticed also from the aspect of the breaking surfaces of iron treated with thermite; in fact, the grains of the iron are much finer, its structure is rather dense, and the iron has a remarkable polishing capacity, any disturbing graphite films becoming so small as not to be noticed by the naked eye. In the case of the amount of thermite being sufficient, the increase in temperature produced by the reaction is materially higher than a simultaneous unavoidable loss by heat radiation; this increase, as well as the reduction of the ferro-oxides dissolved in the bath, will materially

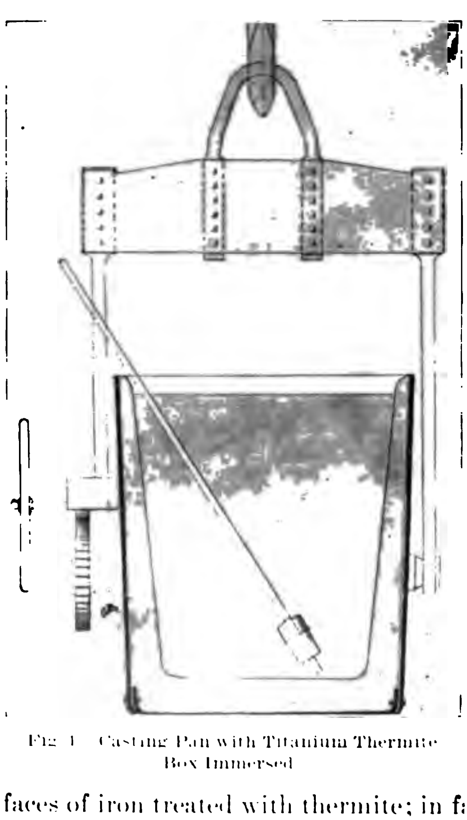


Fig. 1. Casting Pan with Titanium Thermite Box Immersed

augment the liquidity of the molten metal. Finally, the cast iron will receive a certain addition of titanium from the reaction. It is not safe to state whether the addition of titanium, or the mechanical effect of the reaction, is mainly operative in freeing the cast iron from the gases dissolved. It is, however, a fact that the castings are freed from any gas they may contain. Metal surfaces that formerly would spit continuously, become quite motionless after the reaction has been produced.

A further property of titanium is the fact that it will fix nitrogen. In the case of the liquid iron containing even small amounts of titanium, the latter will decompose the atmospheric air, fixing the nitrogen it contains; while the oxygen is made to form a compound with iron, which is dissolved in the liquid metal without necessitating any further reaction. This accounts for the perfect absence of pores in cast iron treated with thermite. The effect of thermite on larger steel castings, in preventing the formation of flaws, is quite analogous. The thermite used to this effect is a special kind known as "flaw-thermite," which is made to act only during the casting process.

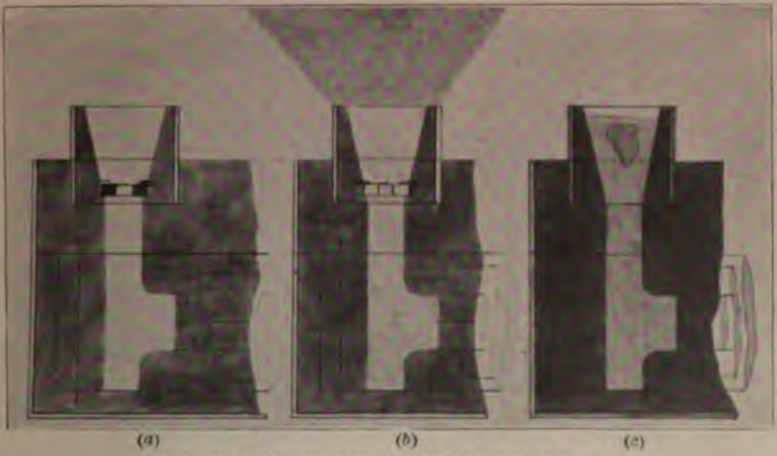

(*a*) (*b*) (*c*)

Fig. 2. Use of Flaw-Thermite in Making Steel Castings. (*a*) Before, (*b*) during, (*c*) after casting process.

In the steel foundry, the formation of flaws underneath the rising funnel is known to be a serious drawback. The steel rising from the interior of the casing into the rising funnels had to traverse the whole of the mould, giving off on its way a large portion of its own heat to the colder walls of the mould. Even in the case of the cross-section of the funnel being very great, the steel filling the latter would therefore in many cases be solidified more rapidly than the steel in the interior of the casting, thus preventing any metal from the funnel returning to the interior of the steel casting to fill up any hollow formed during the solidification. This would result in flaws being formed in most cases immediately beneath the rising funnel.

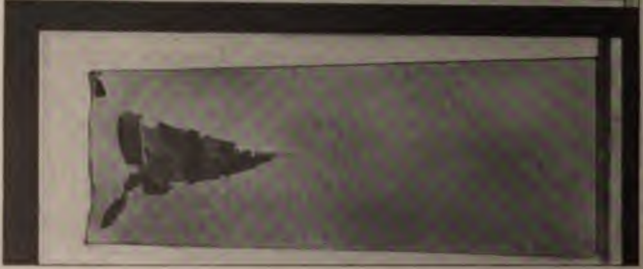


Fig. 3. Ten-Ton Block of Steel, Cast without Use of Thermite, Showing Serious Flaws.

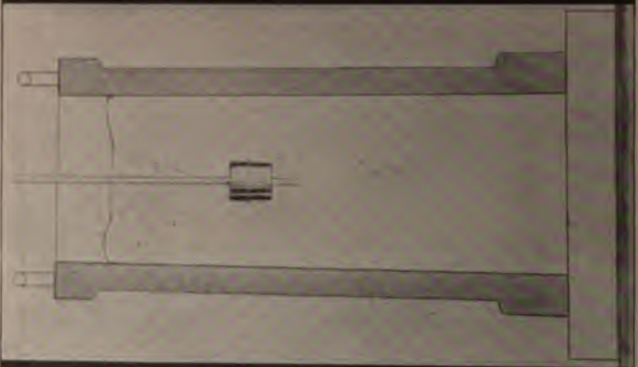


Fig. 4. Diagram to Illustrate Thermite Process of Preventing Flaws in Castings.

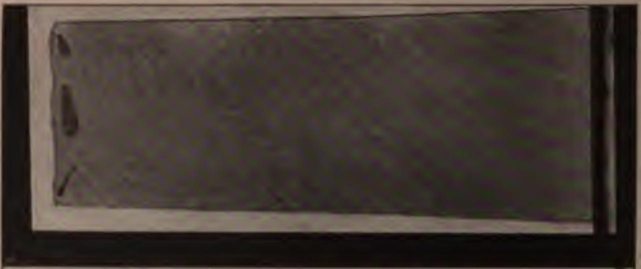
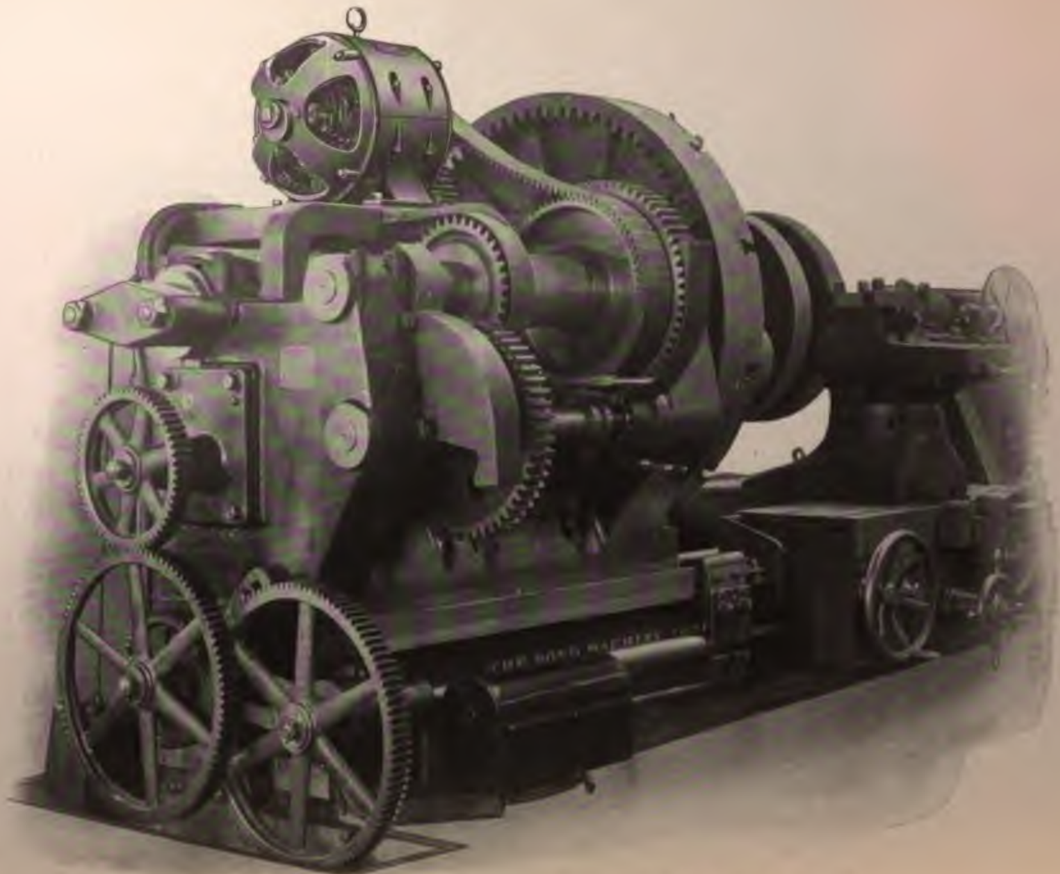


Fig. 5. Ten-Ton Block of Steel.—Flaws Reduced to Minimum by Use of Thermite in Casting.

Instead of the thermite welding process used in many foundries to fill up these flaws, it is much more practicable so to control the solidifying process of steel castings by the use of thermite, as to *prevent the formation of flaws.* Fig. 2 shows a simple way of effecting this. On the left of the figure, is shown a portion of a steel casting mould, into the rising funnel of which a box containing thermite has been fitted before the casting process. The steel rising from the mould into the funnel will traverse the central hole of the thermite box, igniting the contents of the latter. As will be seen from the middle part of the figure, the thermite is burned while the steel fills up the funnel, *i. e.*, beneath the surface of the liquid metal, thus driving the whole of the contents to an extremely high temperature. The steel in the funnel, therefore, remains in a liquid condition for a longer period than the one within the casting. As shown in the third part of the figure (*c*) any flaws will now be formed at a place where they are quite harmless—namely, in the interior of the rising funnel.

Another use of thermite in boxes is illustrated by Figs. 3, 4, and 5, where the manufacture of forgings free from flaws is illustrated. In Fig. 3 is represented the cross-section of a forging block made after the ordinary process. As will be seen, the flaws are developed greatly, reaching 42 per cent of the depth of the block. If a box of thermite be introduced into the block (see Fig. 4) at so late a moment as to allow of the steel throughout the block passing to a plastic condition, the thermite reaction is started instantaneously, when the mass of the block is again liquified throughout; and, the steel filling up any flaws already formed, a funnel of different size, opened upwards, will be formed. The latter should be filled up with liquid steel kept ready for the purpose, whereupon, the thermite slag rising to the surface, a practically perfectly dense block, having only small flaws at most on the upper edge, will be formed, as shown in Fig. 5. Steel blocks of enormous weight have thus been manufactured free from flaws.



72-INCH LATHE DRIVEN BY 15 H.P. THOMPSON-RYAN MOTOR.
350-1750 Rev. per Minute.
Ridgway Dynamo and Engine Co.

MAKING A MACHINIST

The boy, to be successful, must be willing to work and study. He must have ambition and common sense. He should realize that there is a great deal for him to learn before he becomes a machinist. He should have at least a common-school education. He has a good education if he has been taught how to learn and how to think intelligently.

He must be mechanical. If not, he can become a machine hand; that is, he may, after a time, become able to run a machine; but he will never make a machinist in the highest sense of the word. He should be on time at his work. The clock will go faster if he does not watch it, and he will do more and better work. He should study mechanical drawing. He should take a course in a good correspondence school.

He should get together a good kit of machinist's tools as fast as he can afford it; for he will find later that it makes a very poor impression on his shopmates and foreman if he has to borrow tools for the first job given him in a new shop. Cigarette money can be used to buy tools and help the boy. Cigarettes help the tobacco trust and the undertaker. I am convinced that the boy who has formed the habit of smoking cigarettes cannot become a good machinist. I have never seen a boy of this class who was not stupid; and I have not been able to decide whether they smoked cigarettes because they were stupid or were stupid because they smoked cigarettes; but I do know that the boy who habitually smokes them is stupid, dull, listless, dazed, and useless in a machine shop.

The boy should not be discouraged if his foreman does not at once notice that he is the brightest boy that ever came into a shop. He should give the foreman a little time. It will be noticed, if this is so, and that without having to be told about it. He should remember that he has been blessed with two eyes and two ears and but one tongue. This is not a mistake of nature.

He should try how well he can do the work given him, not how much he can do, until he becomes familiar with it. He will find that speed will come with practice. Above all, he must be thorough, and he should think of his work. He should remember that the men in the shop know what he does not know. He will lose nothing by admitting the fact. He should be obliging. If he shows a disposition to take hold and help when needed, he will find that the man helped will help him; and the boy needs it more than the man.

He should take at least one good trade paper. A good trade paper is up to date. The new work—the work that men are doing to day—is being discussed therein, and he will be greatly benefited thereby. Mechanical books are good; but the trade paper is better, because the machinist's business is changing so rapidly—new tools are being brought out and old ones improved to such an extent—that he can keep in the procession only by keeping thoroughly posted. In doing this, the trade paper will be of great assistance. He should read the advertising pages. He should make a collection of manufacturers' catalogues, many of which to-day are good books of reference.

The boy should apply in person for a position. A dear old lady once called upon me to get a position for her boy. After her description I was surprised when he showed up. He said his name was "Willie." He was nearly six feet long and a few inches wide. He was a dear, good boy; but he could not stand the good-natured chaff of the other boys in the shop, and went back to his mother. He was a veritable, irritable mother's boy.

The boy will not be given good work at first. The way to get good work is to do well what is given him. The foreman can judge of his ability only by the manner in which the work given him is done; and he may be certain that he will not be trusted on better work until he has shown that he is worthy of the confidence. The new apprentice, in many shops, has to keep the floor clean. He should remember that oily waste and sweepings are more liable to catch fire when at the bottom of a barrel than on the floor, no matter what is on top to hide them. He should keep the floor clean under the benches. I am always willing to risk the middle of the floor if the boy will clean the corners. The oil that goes on the floor is wasted. It is not necessary to give every part of the machine a bath, although it may be so dry that it is screeching for a drink. Oil should go on the bearing surfaces, and it will not go there if the oil holes are plugged with dirt.

If running a lathe, he should not keep the feed just fast enough and coarse enough to escape the criticism of his foreman. A machine tool should not be abused; but it should be run to its fullest capacity. In roughing out work, care should be taken to leave stock enough to finish, but not enough to make more cuts than are absolutely necessary. Work held in a lathe-chuck should be supported if it stands out far enough to prevent taking a good chip without danger of breaking the tool. It will save time to get the steady rest on it.

In running a planer, the tool must have time to drop back into position for cutting. On fine work, enough space should be allowed for the planer platen to start back smoothly before the tool touches the work; but the platen should have rush orders to get back and do something. The boy is not earning money while the planer tool is cutting air. He must think, on planer work, not how many straps can be used, but how few; but enough must be used to hold the work, and they must be so arranged that the work is not sprung out of shape. The tools must be kept sharp and in good condition.

A hole cannot be tapped out the size ordered if drilled the full size of the tap. A one-inch drill will not drill a one-inch hole if the point of the drill is ground a sixteenth of an inch off the center. The operator should not drill full size into the work before finding out whether or not the drill is cutting where he wants the hole. A twist drill may make the hole just where it is wanted without running off on one side; but if the operator is not drilling through a bushed fixture, he had better find out. He can change it, and make a good piece of work, only if it is done before the drill cuts full size. This mistake is made every day, and it is one piece of carelessness for which there is no excuse. It is the operator's business to know, not to guess, that it is all right; and the fact that it was center-punched and laid out all right does not prevent the drill from running. A tap will not go any further after it has struck the bottom of the hole. We have all proved it. The boy should not try it. He may have more pieces when he gets through, but he will wish he had but one before he gets the broken pieces out. The boy can not ream a hole one inch if he has drilled it an inch and a thirty-second, and he can and will do this with a drill the right size for the reamer, if he is not attending strictly to business.

The boy should not make excuses. It does him no good to tell his foreman that he "did not think of that." He is paid to think of what he is doing, and he will never amount to anything if he does not think. The machinist who has graduated from a large, well-equipped shop is in many cases at a disadvantage when compared with the man who has learned his trade in a large job shop; because the job-shop machinist seldom has everything to work with and must devise means and fixtures for nearly every piece of work given him. He learns to think, and to think quickly and intelligently. He cannot go to the tool-room or stock-room and get tools or material for every job, and he must depend largely upon his own resources. There is no time, on most repair work, to get out drawings or patterns, fixtures or tools. The work must be done, and done at once. The customer is there waiting for it; and often the whole shop knows it, as his factory may be shut down at a great loss.

In the small shop or job shop, the man must be capable of doing his own thinking; and the boy starting in a job shop is generally put helping the older hands, and has a better chance to see and learn how the work is done. In the large shop, a great deal of the planning and thinking is done for him; he is supplied with all the special tools, fixtures and drawings, so that if he is a good machine operator he can do good work; but he can not do it alone. He is part of a machine, and is at a loss when anything new or irregular comes up. In a large, up-to-date shop, he learns the use of modern tools, and sees more of the new methods and fixtures for turning out good work quickly and cheaply; but he does not get the variety of work he would in the smaller shop, and is therefore more apt to beome a specialist on some particular machine—that is, more of a machine operator than a machinist in the largest sense—because economy in production comes from keeping a man on the same work so that he becomes expert in that line. Therefore, in the large shops, we are more apt to find lathe hands, planer hands, milling-machine and drill-press hands, and so on, than the regular all-round machinist. Of course it is much easier to become expert on one machine; but the young man we have in mind is ambitious, and does not intend to be always holding down a job for day's wages. He wants a position with a salary attachment, and therefore he should endeavor to obtain a working knowledge of every part of the machinist's trade. He cannot afford to overlook any part of it. He should know how to do the work himself to be able to direct others later; and he will find that moulding, pattern-making, sheet-iron work, blacksmithing, and a number of other trades are so closely allied with the machinist's trade that he should take advantage of every opportunity to become familiar with all the mechanical trades. He will need it all later; and, once obtained, it is easily carried from place to place, with nothing to pay for excess baggage. He should study steam and its properties, thus becoming familiar with the steam engine and its wonderful simplicity and efficiency; gas and the gas engine and its wonderful eccentricities; electricity and its vivid unexpectedness. In fact, the avenues of knowledge which open up and radiate from a study of the machinist's trade, impress upon us the comparatively small amount of knowledge it is possible to acquire in a lifetime.

The boy will never have learned it all in the machinist's trade. It will take him years, perhaps, to find out how little he knows; but after he does learn this, if he is the right kind of boy, his progress will be rapid. The machinist's trade is hard work in some respects, but extremely interesting. He will get his hands soiled, but the money is clean and honestly earned.

The man who claims that he is doing all he is getting paid for and will work hard to do no more, is generally paid for more than he does, and is at a standstill as far as promotion is concerned. He is liable to be out of work a good part of his time, and abuse of the foreman who discharged him does not help him to get another position. It is the cheap man who is always looking for work—the man who cannot stand alone, and who must have some one else to do his thinking for him. To the boy who is just starting at the foot, the top of the ladder may seem a dizzy height; but if he will work and think, giving his whole mind to what he is doing, he will soon find that the rungs are not far apart and that many of them are already below him. Also, that each step accomplished makes the next one easier. The world owes him a living; but this is not an asset unless he hustles. He should not be too anxious about the amount of his salary at first. All through life he will get less than he thinks he is worth. He may be worth less than he thinks, although not worthless by any means. A man has to earn more than he receives before he can get more; the greater he makes this difference, the greater will be the increase when it comes, and the more apt it is to come. He should get into the habit of proving all that he does; and this habit should enable him, not only to know when he is worth a larger salary, but to prove it to his employer.

The good machinist is seldom out of employment; and while the average rate of wages is less than in some other trades, he has steady work and is inside, so that he does not lose time and wages on account of the weather. An engineer is worth more if he is a machinist and can do his own repairs, or, in larger plants, oversee them and know that the work is done correctly. A thoroughly good machinist has learned to take nothing for granted, and knows that "eternal vigilance is the price of good work." For this and many other reasons, his training fits him for positions of responsibility; and the chances of successful careers for bright, capable boys are better to-day than ever before in the machinist business. One of the hardest things in life is the fact that a man has to have years of experience before he is willing to admit, even to himself, the magnitude of his ignorance. It is only the very young who know it all. The young man of twenty is willing and anxious to give advice; the man of forty is willing to pay to get it, but he seeks it from men of experience.

In the line of invention, the opportunities are greater than in any other business. The machinist may obtain patents for his inventions, which, when assigned to his employer, may be worth thousands of dollars to the latter, and this often without losing his position; while he has the satisfaction of knowing that his inventions have advanced the interests of his employer if not his own. And you know we are taught that it is not right for the employee to be too selfish. The inventor has probably done more for the world and less for himself than any other individual. And this is none the less true because, when the patent is allowed, he usually wants an even million dollars for it. Many inventors still want it.

The world owes more to the machinist than is generally realized. The splendid position of the United States in the world to-day is largely due to her machinists, who, by their special tools and labor-saving machinery, designed and built by machinists, have made it possible for her to compete successfully with foreign manufacturers, and have enabled her to sell and to deliver to all parts of the world, freight paid, manufactured products at a less price than the cost of manufacture would be in those places, and this at a fair profit. The unfair profit is obtained by charging her own citizens a higher price, and allowing them to pay the freight. The fact that we can build better bridges, build them cheaper, and deliver them on time—and the time about half what other countries require—is largely due to our labor-saving machinery. The *Oregon*, the rapid-fire gun, the bicycle, the horseless carriage, the steel sky-scraper, the Brooklyn bridge, the locomotive, the sewing-machine, have all been made possible and practicable by the machinist. In fact, it would be next to impossible to mention anything manufactured that does not depend more or less for its excellence upon the machinist. He manufactured the article in question, or he made the machine that manufactured it; and he designed and made the tools that made the machine possible.

There is, perhaps, no other trade, and very few professions, that require the high order of intelligence, the study, the application, the real hard-headed common-sense, the surgeon's delicacy of touch—for instance, in the fitting of fine work—that the machinist's trade demands to give the excellent work and the interchangeability of parts found in the modern rifle or sewing-machine. The range of his work is from a needle to a battleship; from automatic machinery that "would talk French if it had one more movement" to measuring machines guaranteed not to vary more than the fifty thousandth part of an inch from the absolute. This precision will perhaps be better appreciated when it is remembered that one hundred and fifty times this limit of variation is only equal to the diameter of the average human hair Standard plug and ring gauges, to take a specific example, are so accurately fitted to each other that the expansion due to the warmth of the hand, if the plug be held in it for a few moments, will make it impossible to insert the plug in the ring; while if the ring be expanded in the same way, the plug will drop clear through it.

When the machinist has become skillful enough to fulfill the above requirements, he may receive from $2.50 per day up to whatever he can make himself worth and prove it. The wonderful activity in manufacturing at the present time will increase owing to the growth of the United States; or the growth of the United States will increase owing to the wonderful manufacturing activity. Whichever way you look at it, machinists will be in demand; and, although we have so many first-class men, the demand for really good men is greater than the supply.

ELECTRIC LIFTING MAGNETS

One of the most interesting modern applications of electricity is its use in connection with electromagnets for the lifting of loads. An apparently immaterial alteration in the construction of cranes and traveling platforms in foundries, steel works, rolling mills, blast furnace plants, etc., where loads had formerly to be lifted by hooks, has resulted in a saving of labor and in an increased efficiency of operation wherever electromagnets have been resorted to in the course of the last few years.

Whereas American constructors, who first devised this use of electricity, employed electromagnets with open coils, Belgian firms, and in the first place the International Electric Engineering Company of Liége, prefer enclosing the coils completely, so as to enable them to be used without any inconvenience in the open air, while obtaining an efficient mechanical protection against any kind of mechanical injury to which they are liable to be exposed.

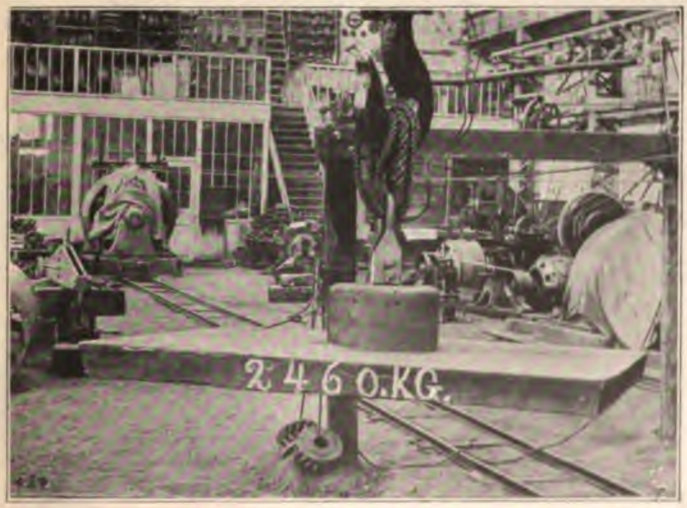


Fig. 1. Single Magnet.

It may be said, however, that the construction of such electromagnets for lifting heavy pieces of iron and steel has always offered serious difficulties and that only a few constructors have been really successful in designing a satisfactory type of apparatus. The International company, who made a specialty of the construction of electrically driven cranes for use in iron and steel works, etc., paid much attention to the problem of lifting magnets, and eventually obtained rather satisfactory results in this line By the courtesy of that company we reproduce illustrations of a few of its magnets.

One of the main advantages afforded by electric-lifting magnets is the saving just referred to in time and manual labor. When attaching the load to the hook of the crane by means of ropes or chains, the services of at least two men were required for the handling of heavy pieces. Now, the electromagnet does away with both the ropes and the men to fix them, all the operations being carried out by the driver of the crane. He it is who lowers the magnet on to the piece of metal to be lifted and excites it by means of the switch which is placed in his cabin. When the

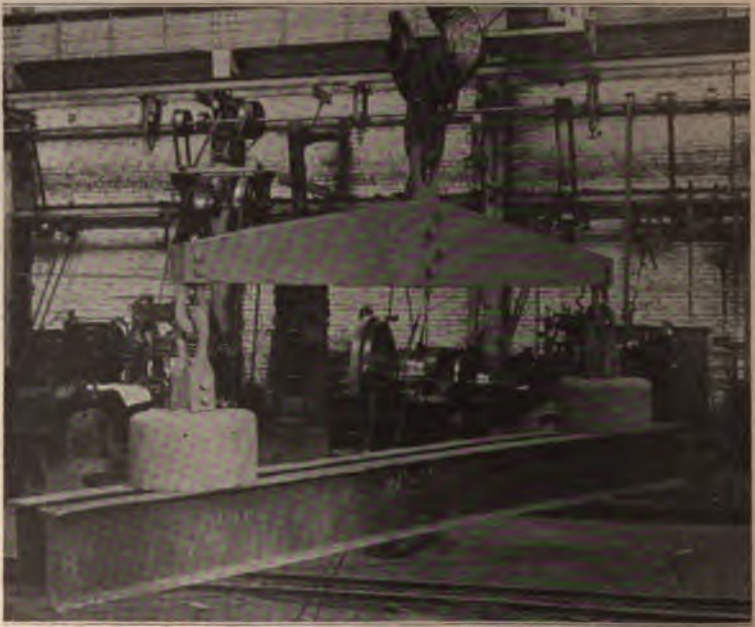
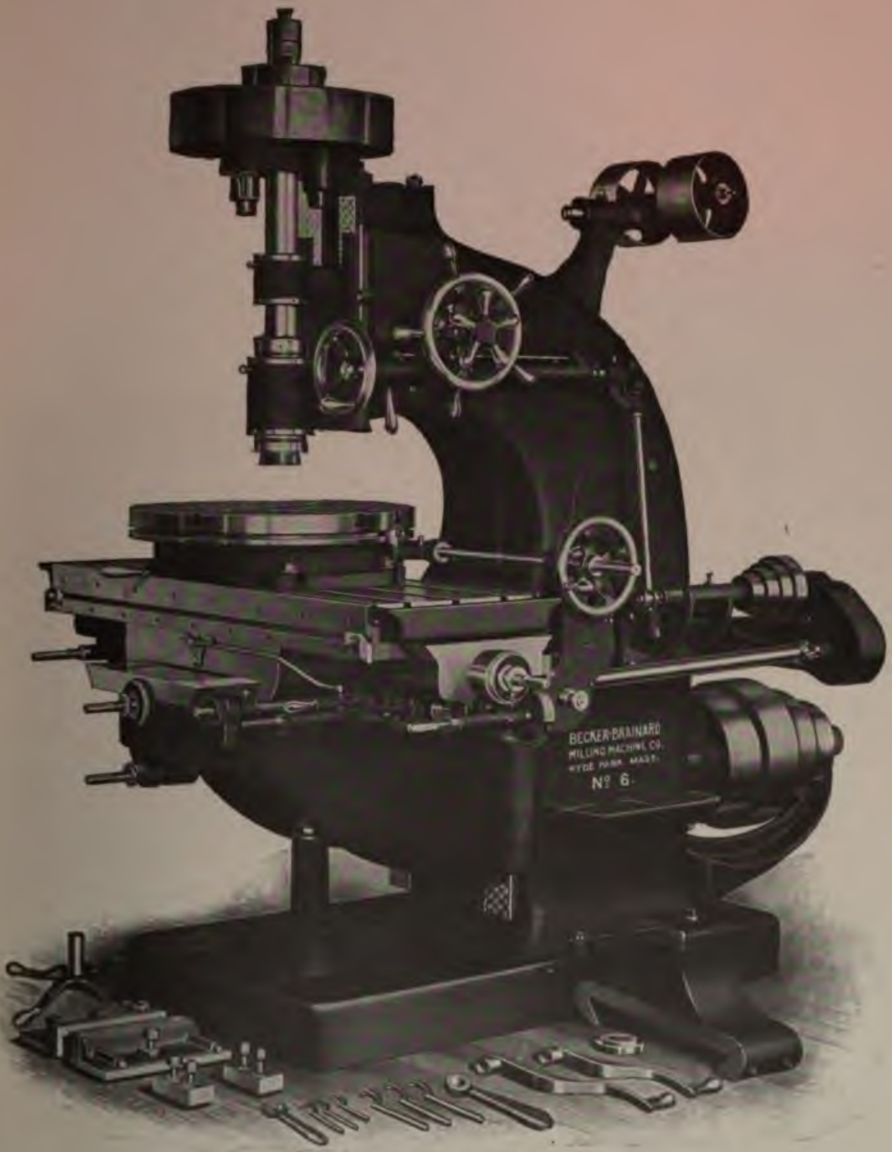


Fig. 2. Double Magnet for Lifting Girders, etc.


BECKER-BRAINARD
MILLING MACHINE CO.
HYDE PARK MASS.
Nº 6.

MILLING MACHINE.
Becker, Brainard Milling Machine Co.

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load reaches the place where it is desired to drop it, the driver lowers the magnet and finally cuts off the current.

The time occupied in picking up the load with magnets is very short; in fact, two or three seconds are quite sufficient; so there is an enormous saving in this respect, while the performance of a given crane is materially increased, the result being that the works can be run with fewer cranes.

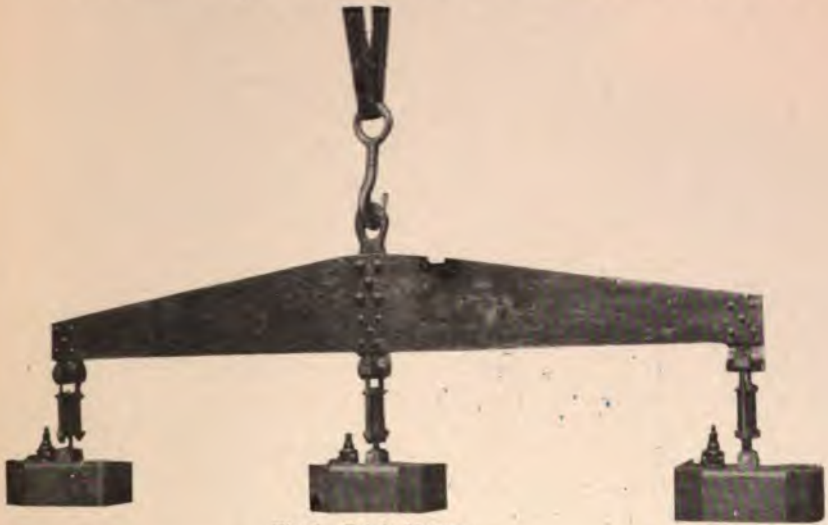


Fig. 3. Triple Magnet.

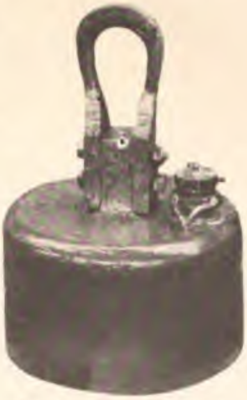
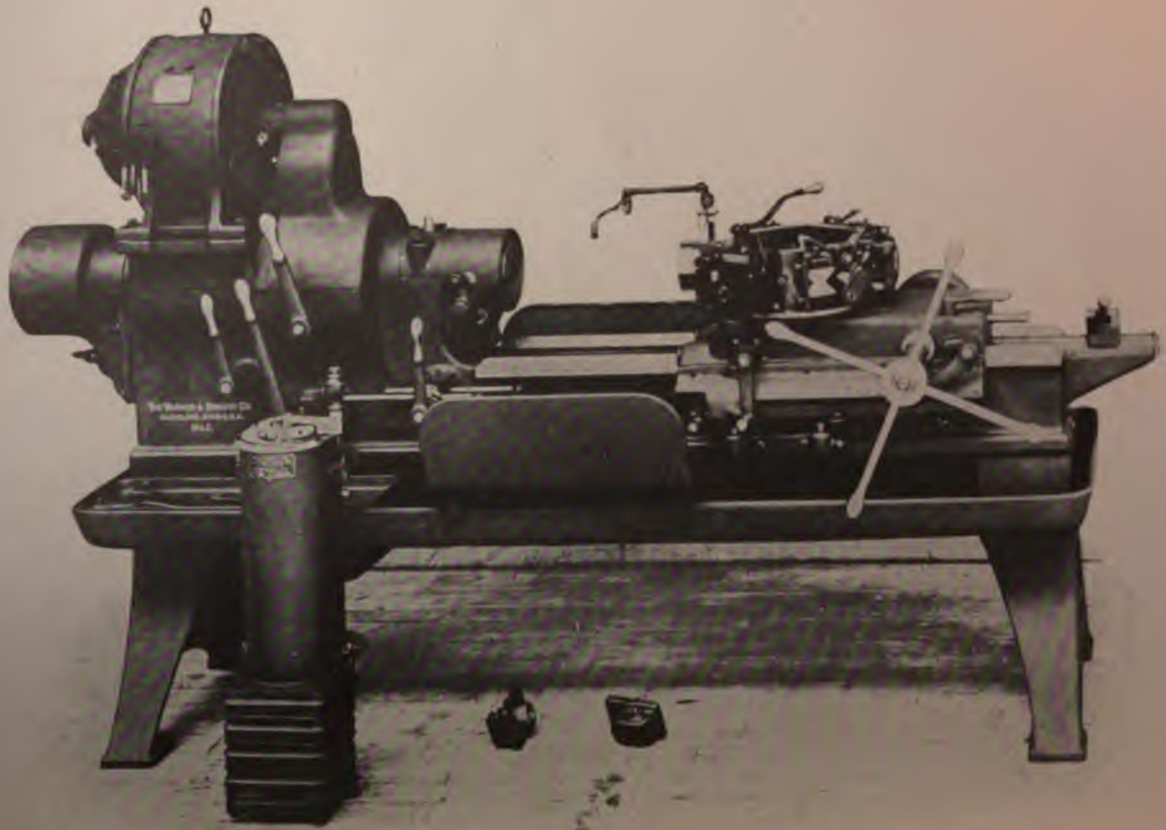


Fig. 4. Electric Lifting Magnet.

The greater consumption of power which is doubtless connected with this additional use of electricity is quite an insignificant item, as a magnet capable of suspending two and one-half tons requires only about 750 watts.

The International company's magnets are mostly of two kinds, represented in Figs. 1 and 2 respectively. The kind seen in Figs. 1 and 3 serves for the handling of sheets and ingots, while the other type is used in connection with girders and the like. The first type is an electromagnet where the magnetic circuit is formed by an internal core and an external bell-shaped cover and is completed by the piece to be lifted. The other type seen in Fig. 2 is composed simply of two single type magnets fixed one at each end of a beam, suspended in the center from the crane hook. Fig. 4 shows the magnet as it appears when ready for fixing to the crane.

It may be mentioned that the magnets can be used also for lifting very hot pieces of metal, which makes them especially useful in foundries, rolling mills, etc. The current is supplied by two parallel wires extending the full length of the crane, connections to them being made by contact pieces fixed to the crab.



WARNER AND SWASEY TURRET LATHE WITH BALANCED THREE-WIRE EQUIPMENT.

Controller within Easy Reach of Operator.

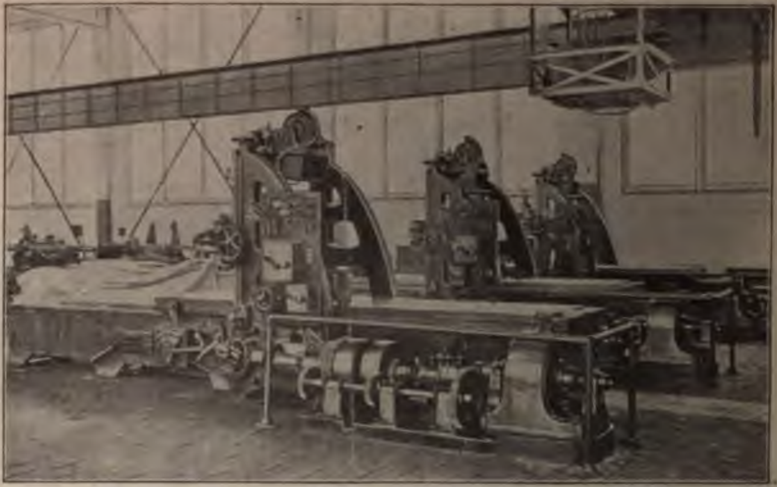
MAGNETIC CLUTCHES

Since the advent of individual motor-driven machine tools, the successful application of magnetic clutches has made possible the operation of an entire machine shop concerning which it may be said—"There is neither line shaft, counter-shaft, nor belt therein."

The utilization of magnetic clutches in driving planers has made a decided difference in the economical operation of these machines, as it has increased the output by making possible a variety of speeds, the operator being enabled to change the speed to suit the work. The planers can be run at a much higher speed than formerly, as there are no belts to slip or burn, and, in securing high speeds on belt-driven planers, the belts would have to be made so heavy that considerable difficulty would be experienced in shifting them. Magnetic clutches, moreover, are very positive in their operation, so that it is possible to work very close to a shoulder or offset. A test was made on a 96-inch planer by setting it so that it would run the tool within 1-32 inch of a shoulder; one hundred strokes were made, and the reverse did not vary enough to allow the tool to touch.

In using these clutches, a machine can be thrown out of action from any number of points at any distance, depending on the number of switches placed in the clutch circuit. The current required by the clutches is surprisingly small considering the amount of power transmitted; on a certain planer it required only .75 ampere to pull two cuts through cast iron, each being 3-32 inch x 2⅓ inch, at the speed of 14 feet 3 inches per minute. This cut does not really indicate how much the clutches will pull as it is just the ordinary work accomplished by the machine mentioned. One of the clutches in use on this planer was tested by putting a strain of 60,000 pounds on it in an attempt to separate the armature from the magnet. How much more than this it would have successfully withstood, cannot be stated, as the parties making the test would not put any greater strain on their apparatus. This test was made on a 33-inch clutch.

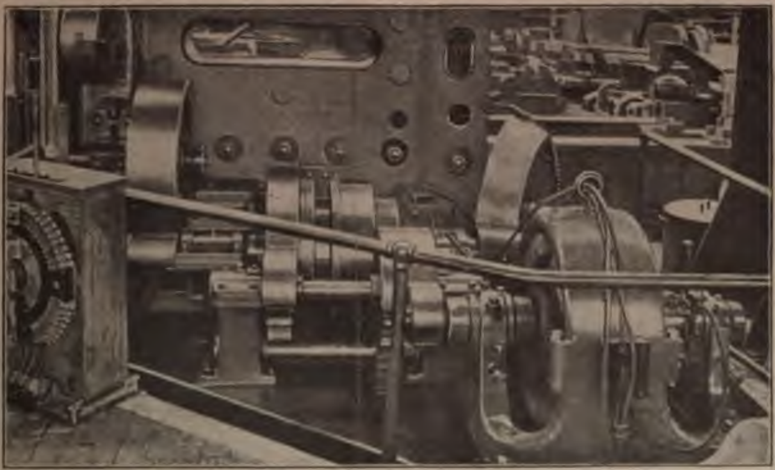
In the accompanying illustration of a 36-in. x 36-in. planer, it will be noticed that there are three gears of different diameters on the left-hand clutch, and there is a field rheostat on the side of the housing of the planer; this will give three different speeds by changing the gearing, and a variety of intermediate speeds from field regulation on the driving motor. The driving member, in this case, is an ordinary shunt-wound motor driving a pair of clutches through what is known as a "five-gear reverse." The right-hand clutch controls the return of the platen; and, as the driving and driven gears are of about the same size, a very high speed is obtained.



Pond Planers, 36 x 36-inch, Operated by Magnetic Clutches.

A magnetic brake is shown at the right of the clutches, and is a very important adjunct to this equipment; should the planer be working very close to the limits of its stroke and the power fail, the platen cannot drift beyond safe limits, as the brake will set and stop the machine instantly. The brake also comes in very handy in setting up work, as the operator can depend upon it to stop the instant he opens the switch.

Magnetic clutches have been very successfully applied to machines for tapping out pipe fittings; in these machines the taps are run in a certain distance, and then reversed to run them out. The tapping machines run at such high speeds that ordinary mechanical or friction clutches will not stand up to the work, or, if the clutch is made heavy and positive enough to do the work, it soon tears the machine to pieces; every time the mechanical clutches would reverse, the jar would affect the entire shop. Since magnetic clutches have been applied, however, the machines reverse so noiselessly that it is necessary to watch them closely to tell when the reversing occurs. The line shafting in shops and mills can be connected up in sections by using magnetic clutches; and any section can be instantaneously disconnected by snapping a switch located anywhere in the shop, or from any one of a number of points, as might be desired.



A 72 x 72-inch Detrick & Harvey Planer Operated by Magnetic Clutches.

Magnetic clutches can be so arranged in connection with counter-shafts that, instead of using a belt shifter, a small switch fastened to the machine is all that the operator will have to move. By this arrangement the counter-shaft does not have to be located directly over the machine, as is the common practice at present. This system of clutches is almost ideal for use in cotton or woolen mills, where it is absolutely necessary to stop a loom instantly should a thread break in the weaving. It requires very little force, and but an instant of time, to set or release a magnetic clutch; and it does not require any more exertion to set a large clutch than it does to set a small one; in either case it would require about the same effort as to switch on or off an ordinary incandescent lamp.

Residual magnetism has been the great bugaboo in most of the attempts to use magnetic clutches, but this source of trouble has been eliminated so that their positive operation can be depended on. There is hardly a limit to the amount of power that can be transmitted; and, considering the ease with which magnetic clutches can be operated, it seems that there is a great field for them when they come to be thoroughly understood. As they have already proven very practical, any person with mechanical ideas and a little ingenuity can see many more uses to which they can be put than those mentioned here.

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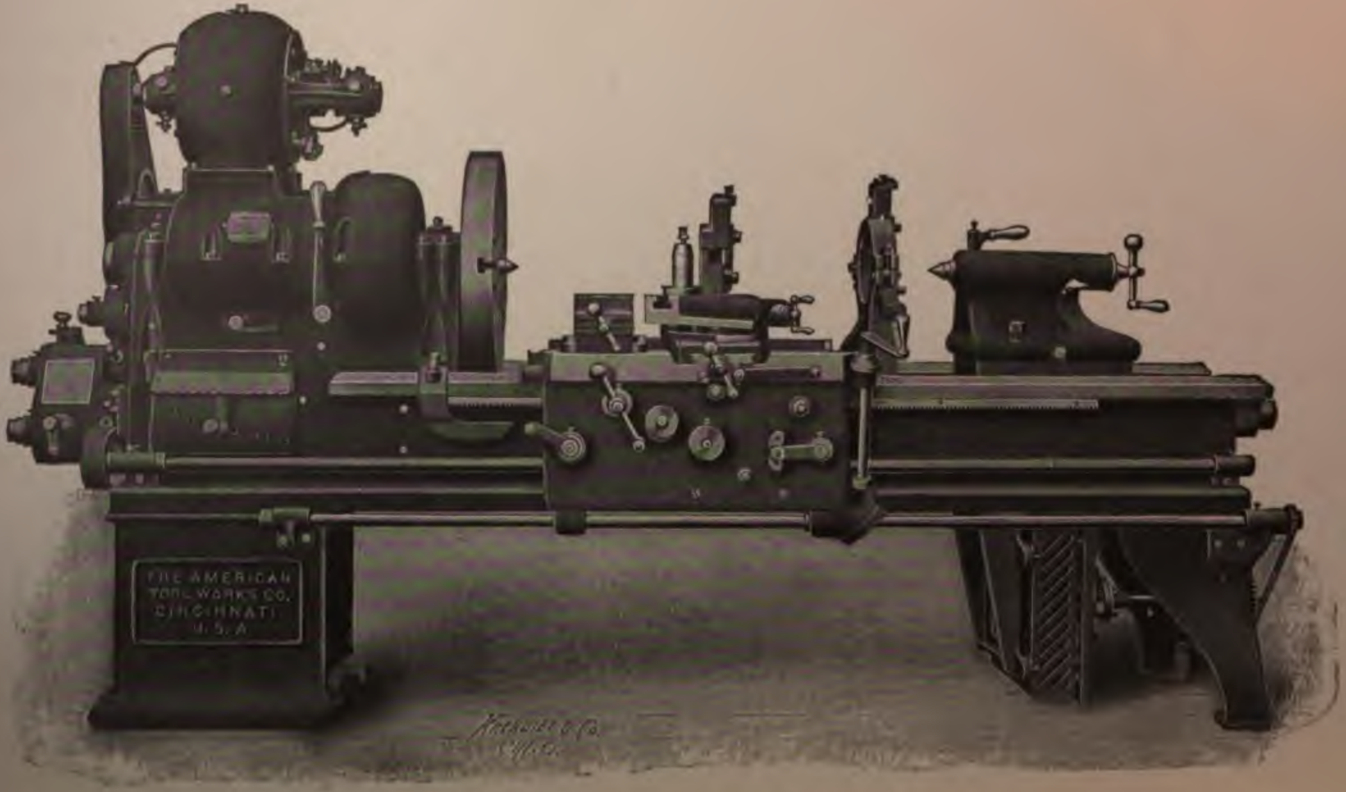


MOTOR-DRIVEN AMERICAN ENGINE LATHE.

THE IDEAL FOREMAN.

Qualifications Requisite for His Highest Success.

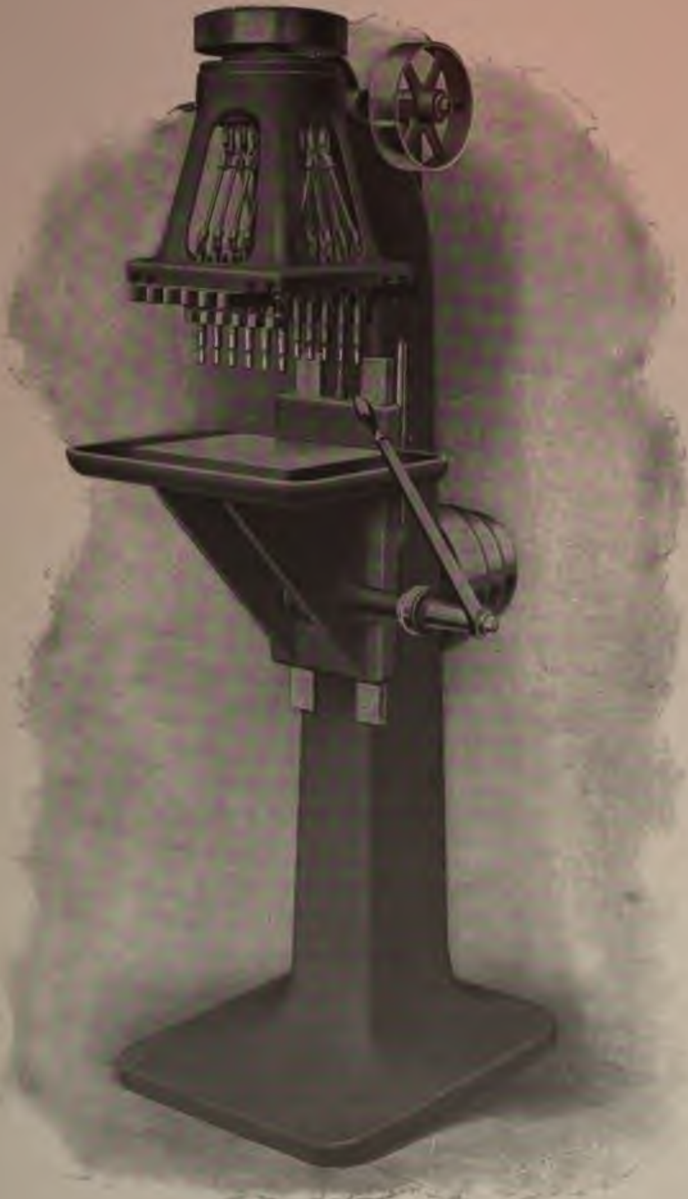
Any attempt to outline an ideal is apt to be met with many differences of opinion, if not actual denials. One reason for this difference of opinion is found in the fact that ideals are always on a sliding scale The ideal of to-day becomes the realization of to-morrow, and the point of view depends upon how far up the ladder of idealism the observer has advanced. To borrow an illustration from the shop, probably every workman remembers that on entering the factory as an apprentice, his boyish ambitions were centered on advancing to a position occupied by some workman well up the line, who, in the opinion of the apprentice, was better dressed and had an easier task than his fellows. In the course of time, if the young man was ambitious and persevering, he probably occupied this or a similar position, and then found, to his dismay, that his ideal had changed, and that he now looked forward to occupying the position held by the foreman or superintendent. In other words, viewed from the point of attainment, an ideal is a will-o'-the-wisp, always keeping just beyond our reach. It is well that this is so, for there is no human failure so complete as the man who is entirely satisfied with himself.

From another point of view the ideal is a movable feast, because, to quote an example from our subject, the ideal foreman of the apprentice is not that of the skilled mechanic, while the views of the owner on this subject are almost sure to be at variance with those of any of the workmen. We can readily appreciate how the bright boy idealizes the man who treats him kindly and who gives him an opportunity to learn. The lazy boy feels kindly disposed toward the foreman who gives him an easy task. The poor and careless workman wants a foreman who will pass work which is not a credit to the craft, and who is blind to the evils of laziness and, possibly, to those of the drink habit. The skilled workman asks nothing of a foreman but to be treated like a man, to be given a proper share of the desirable work, and to be allowed to work out his own salvation along these lines. The owner looks to his foreman to make money for him. In many cases, he expects him to make more money than the capital invested and the methods pursued will warrant. This means that the foreman is expected to crowd the workmen to the limit, and to keep both the plant and the help as near the breaking point as it is possible to carry them. Some owners and managers, however, are content with a reasonable return on their property, pursue up-to-date methods, and give to the workmen some thought beyond their mere capacity to earn dividends. It is to be regretted that men of this type are not more often found in positions where their humane policy can be held up as an example to those of a more sordid and grasping nature.

It having been shown impossible to outline an ideal foreman, when viewed from these different standpoints, evidently the discussion of what a foreman should be can be no more than a statement of the personal opinion of the writer.

Before all other qualifications, it is necessary that the foreman should be what the word implies—first, a man; and, second, a leader. If he is a man in the true sense of the word, he cannot fail to be respected by all self-respecting workmen. If he is an honest leader, he will conduct those workmen along the lines laid down by the owners as the policy of the establishment. Too often the foreman is looked upon merely as the buffer between the firm and the men. He is supposed to act as peacemaker, and to keep them from flying at one another's throats. Under such conditions, it is obviously impossible that a man can be in full favor with either party. Toward the firm the foreman should be respectful, obedient, and energetic; toward the workmen he should be firm, just, and sympathetic.

Of all the qualities going to make the ideal foreman, that of tact is the most important. It means that the men will be treated as individuals, their failings noted and corrected, their good points enlarged upon and due credit allowed for them, and that the shop life will be freer and more natural. With this tact, or faculty of governing along the line of least resistance, must be coupled absolute fairness. Nothing will create such an atmosphere of discontent as a suspicion that the foreman has favorites. If these supposed favorites happen to be relatives of the foreman, the idea is much harder to combat. For that reason, personal friendship



MULTIPLE SPINDLE DRILL.

Pratt and Whitney Co.

and family obligations will be left outside the shop by the man who wishes to succeed as a leader of workmen. A decided, but not aggressive, manner of passing upon questions serves to inspire the men with respect for the foreman, especially if such decisions are rendered promptly, and they prove in the large majority of cases, to be accurate. Having made a decision, or taken a decided stand on any matter, it will not do to deviate from that position, unless it is so clearly wrong as to be apparent to the casual observer.

Fairness, dignity, and firmness are qualities that can be quite closely defined; but tact and its fellow attribute, executive ability, are rather elusive of close description. They are of the inherited type and can be cultivated only to a very limited extent. If a man does not possess tact and executive ability, it is useless for him to accept a position where they are essential, in the belief that they will develop as required.

While workmen are supposed to be paid only for the time spent in the shop, it is also true that a man's value cannot be reckoned entirely by the quality of his work and the number of hours of labor. His conduct outside the factory invariably leaves its impress on his conduct within and on the product of his work. This is even more noticeable in the case of a foreman, for, although workmen generally would deny it, they do not and cannot have a wholesome respect for a foreman who is not respected by the community. Men will say they do not care what a foreman is outside the shop; but their better nature will not allow them to look up in any sense to a social pariah.

While an absolute grasp of all the details of the business, viewed from the workman's standpoint, is not absolutely necessary to a foreman possessing tact and executive ability, it adds greatly to a foreman's prestige to be able literally to show any workman just how any operation should be performed.

Just a word in illustration of tact in dealing with men of radically different temperaments. The blustering workman, so familiar to all foremen, can be best controlled by a very quiet and soft-spoken superior, especially if the foreman in question has the reputation of firmness and fair dealing. The quiet, positive statement, coupled with a refusal to discuss the matter, is so contrary to the blatant workman's usual procedure, that it takes away his only weapon by not allowing him to use it. On the other hand, it often happens that the quiet man of few words can be spurred on to better deeds by an energetic and insistent manner on the part of the foreman. Of course, this all goes to prove the foreman's tact, and to disprove the oft-repeated statement that workmen should all be treated alike. The best results cannot be obtained in this manner. Until men are all turned out in the same mould, it will be necessary to suit the treatment to the temperament of the man.

The question of how far it is advisable to show sympathetic nature, is one of grave doubt. Sympathy does not mean that excuses are to be taken literally; but a casual inquiry as to how the sick wife or baby is getting along shows an interest outside the commercial relation that appeals to most men. The old saw, "You catch more flies with molasses than you do with vinegar", has an application in the treatment of workmen by their foreman.

Another question which has more than one answer, is whether it is better to have a foreman promoted from the ranks or to get an outside man for the position. The man from the bench is familiar with all the shop traditions and practices, and can keep things going with hardly a break. On the other hand, he is the victim of jealousy and spite, and, unless exceptionally well-poised, is apt to assume an attitude toward his former shopmates which might be termed "dignity gone to seed". Every youthful indiscretion is remembered, and any attempt to check such antics on the part of the younger men is held to be an unwarranted assumption of dignity. On the whole, the attempt to promote a foreman from the floor or bench is fraught with difficulties; and many a man who would have made an excellent foreman in another shop, has been a rank failure in that capacity when tried among his old shop associates. The foreman taken from the outside stands or falls, as far as the workmen are concerned, on his record in his new position. He is not condemned for past faults. Furthermore, he should be able to bring into his new associations some of his experience in former situations which will be of value to his new employers. It is an infusion of new blood and is often the means of discovering leaks and weaknesses not noticeable to the old employees.

A foreman's value to a firm depends largely on his knowledge of the capacity and limitations of each man under him. This knowledge enables him to lay out his work to the best advantage, as he knows the man who is quick, the man who is accurate, and the man who can be trusted to carry along detail or experimental work. To keep a man up to his best pace, to have new work laid out for him in advance, and to keep that man satisfied with his work and wages, is a task that taxes the ingenuity of the best of foremen. The matter of repairs, especially those of a petty nature, is one which tests a foreman's commercial sense more than the regular run of work does. As an example, suppose that the friction on a countershaft slips; shall the oiler be sent for while the machine operator waits; shall the workman fix it himself; or shall the man be transferred to another machine while the repair work is going on? Of course, this all depends on the nature and degree of the difficulty; but it affords an opportunity for quick and accurate judgment on the part of the foreman, and demonstrates his fitness to cope with emergencies.

An article of this character should not be closed without a reference to that old-time figure, the "working foreman". Do not all machinists of mature age remember how the foreman would walk down the shop with a piece of work and a file in his hand, filing as he went? Even in these days of strenuous competition, we sometimes see an advertisement for a "working foreman". It is preposterous to think that a foreman can properly supervise the operations of more than a dozen men, and do any work that calls for close attention. Many firms insist on this practice, however, and are daily losing money by its continuance. A foreman should be devoting his energies to the development of better methods of manufacture, and not to the production of work that could be performed by one of the machinists.

And so we leave the ideal foreman, not yet discovered, not even closely defined, but anxiously awaited and badly needed.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

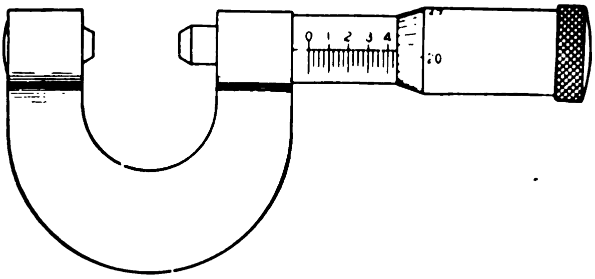
MACHINE SHOP WORK.

PART I

1. What are limit gauges?

2. When are calipers used? and how are they set?

3. If there are 40 threads per inch on the micrometer screw, what is the reading of this micrometer?



4. What is a soft hammer, and when is it used?

5. What is a chuck drill?

6. What methods are used for cleaning a file?

7. How should a file be held for fine filing?

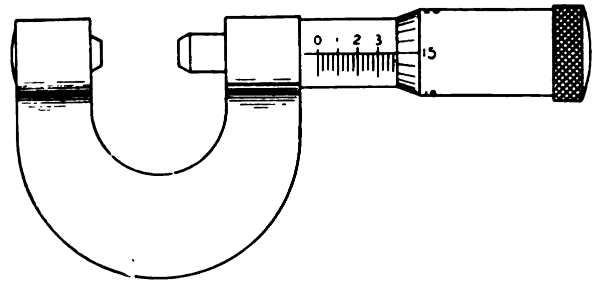
8. Describe the surface gauge.

9. Describe the micrometer caliper.

10. Describe two common forms of chisel, and state under what conditions they are used.

11. Why is not the cutting surface of a file perfectly flat?

12. Give the reading of the micrometer caliper when in the position shown.

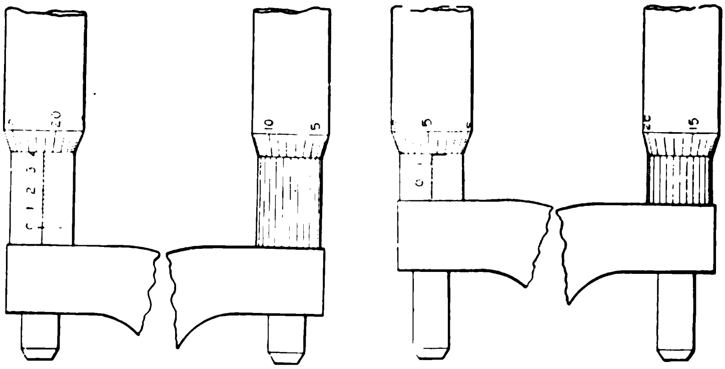


13. What methods are used for holding a file for filing large surfaces?

14. Describe the twist drill.

15. What is a vernier?

16. What is the reading of the vernier micrometer caliper when in the positions shown?



17. What is the result when the lips of the twist drill are of unequal length?

18. When are reamers used?

19. How much less should the diameter of the drilled hole be than finish size if a reamer is to be used?

20. Explain the methods of cutting screw threads with a die.

21. What advantage has an adjustable reamer over a solid reamer?

REVIEW QUESTIONS

ON THE SUBJECT OF

MACHINE SHOP WORK.

PART II

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1. What is a mandrel?

2. Describe the rise-and-fall rest.

3. How long will it take to turn a chip 18 inches on a shaft 24 inches long and 3¼ inches in diameter?

Assume cutting speed 20 feet per minute.

Assume feed $\frac{1}{50}$ inch per revolution.

4. Describe the process of making a taper fit.

5. The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 18 threads per inch?

6. Describe the process of bringing the countersink back to center.

7. For what purpose is the back gear of a lathe?

8. Describe some method of adjusting pieces to center.

9. Describe the shapes, and state the uses of the following lathe tools: Diamond point, side or facing tool, parting tool, and square-nosed tool.

10. Why are lubricants used in turning?

11. Describe the method for finding the clearance for a tool for cutting square threads.

12. On account of not having the proper gears at hand compound gears must be used. The lead screw has 4 threads per inch, and a screw having 9 threads per inch is to be cut. The gears chosen for drivers are of 24 teeth on the spindle gear and 30 on the intermediate. What gear should be used for the intermediate driven if the screw gear has 60 teeth?

13. Describe the U.S. Standard thread.

14. Describe the steady rest.

15. How would you adjust a piece to center if the hole must be run true?

16. Why should a boring tool have more clearance than a turning tool? Explain with sketch.

17. Explain the method of turning a taper by setting the tailstock over.

18. In what direction does the carriage run when cutting a right-hand thread?

19. A screw of 14 threads is to be cut in a lathe having a lead screw of 3 threads per inch. Compound gears are to be used. The gears available have 20, 30, 40, 50, 60, 70, and 80 teeth. What ones are to be used and where?

20. How is motion transmitted from the cone pulley of a drill press to the drill?

21. How is motion transmitted from the spindle to the lead screw?

22. Describe clearance and rake as applied to a lathe tool. Give approximate values in degrees for cutting steel.

23. Should a tool for turning brass have rake? Why?

24. The end of a piston rod is to be turned tapering. The piston rod is 28 inches long; the tapered portion is to be 3 inches long. The diameters of the taper are to be $2\frac{3}{4}$ inches and $2\frac{5}{8}$ inches. How much must the tail block be set over?

25. Suppose the lead screw of a lathe has 4 threads per inch and we wish to cut 11 threads per inch. The gear on the spindle has 20 teeth. What gear should be chosen for the lead screw?

26. What is a universal radial drill?

27. In what ways is a twist drill preferable to a flat drill? How is the drill made to turn with the spindle?

28. Describe the universal chuck.

29. Why should not a tool be set too high?

30. How long will it take to turn a chip from a shaft 37 inches long $5\frac{1}{2}$ inches in diameter?

Assume cutting speed 23 feet per minute.

Assume feed of $\frac{1}{32}$ inch per revolution.

REVIEW QUESTIONS

ON THE SUBJECT OF

MACHINE SHOP WORK.

PART III

1. What is interchangeable work?

2. Explain the method of grinding valves.

3. What is pickling?

4. In what direction relative to the motion of the cutter should the work on a milling machine be fed?

5. What is the difference between pening and bending?

6. What is the difference in the rates of revolution given for surface milling of cast iron, with a surface milling cutter 3½ inches in diameter, according to Addy's rule and the Brown & Sharpe table?

7. What are the principal uses of the grinding-machine?

8. What is a surface plate? Describe the process of making.

9. Describe the hydrostatic level.

10. What is the safe rate of revolution of an emery wheel 5 inches in diameter, if its surface speed is not to exceed 4,000 feet per minute?

11. A surface of cast iron is to be finished in one cut on the milling machine. The casting is 8 inches long and 5 inches wide. The milling cutter has a diameter of 3 inches and the width of 2 inches. How long will it take to do the work? Assume feed of 2½ inches.

12. What is a lap? Of what metal should it be made?

13. How may a permanent joint be made?

14. Describe in a general way the setting of a machine.

15. What should be the diameter of a piece as it comes from a lathe if it is to be ground to a diameter of 4 inches?

16. According to Addy, how long would it take to mill a cast iron surface 18 inches long, and 16 inches wide, with a milling cutter 6 inches in diameter and 3 inches wide.

17. How is a surface prepared for laying out work?

18. How are temporary joints made?

19. How many horse-power may be safely transmitted by a single belt 8 inches wide, running over a 36-inch pulley which makes 175 revolutions per minute?

20. State some of the uses of the milling machine.

21. How are case-hardened pieces usually finished?

22. What tools are used for laying out work? Explain the function of each.

23. Why should a lathe or planer tool work beneath the surface of a casting?

24. How may the power transmitted by the belt in Question 19 be increased to 32 horse-power?

25. According to Addy's rule, what should be the speed of a milling cutter 8 inches in diameter when working in cast iron?

26. Which is preferable for high polish, new or old emery cloth? Why?

27. If the feed is 1.5 inches per minute, how long will it take to cut a groove 2 inches wide, 4 feet long, ¼ inch deep? The material is soft machinery steel, and the milling cutter is 2¼ inches in diameter and 1¼ inches wide.

28. Should work be calipered while at rest or while in motion?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART I

---

1. Give the meaning of approximate and precise measurements. Give examples and reasons for employing either method when doing the individual piece of work.

2. When making single-lip drills why is it necessary to remove exactly one-half the diameter as shown in Fig. 19?

3. When making the taper reamer, called a stepped reamer (Fig. 51) why are the steps made straight rather than tapering?

4. When a mandrel is held in V blocks when laying off the center line as shown in Fig. 67, how would you find the exact location by precise measurements?

5. Why is it advisable to cut the threads of an adjustable tap somewhat smaller than the desired size for the tap to cut?

6. What would be the effect if a piece of work were turned to finish dimensions, when the live center of the lathe did not run true? If the dead center is not to gauge?

7. Why will a twist drill cut faster and make a truer hole than a flat drill?

8. State in your own language the result attained by using a reamer holder of the design shown in Fig. 58.

9. When extreme accuracy is required, why is not advisable to grind the essential part of a milling machine arbor before it has the spline cut?

10. Why is it desirable for a tap to retain its correct pitch when hardened? What would be the effect were it to elongate? What if it should contract?

11. How should a piece of round tool steel be centered for turning in the lathe?

12. Explain the method used to prevent a fluted reamer from chattering. What should be taken into consideration in designing the tooth?

13. When making mandrels why should the center holes in the ends be deeper than in the case of most tools?

14. When is it allowable to cut the threads of a tap by means of a screw-threading die?

15. State in your own language the objection to reaming holes that must run perfectly true, and why it is considered allowable to ream a hole that is to be approximately true as, for instance, the hole for receiving the tap in the tap holder shown in Fig. 105.

16. When is it advisable to use a high-carbon tool steel? When a low? Give example.

17. When cutting the grooves in a reamer having 8 cutting edges, state the number of holes the index pin should be moved each time in order to get an uneven spacing that will diverge by 2° to 4° from an angle corresponding to equal spacing. Assume that the dividing head on the milling machine requires 40 turns of the index pin for one revolution of the spindle. Assume the pin to be set in the circle having 20 holes.

18. What would be the result if the centers were not given the extra countersink, or recess cut as shown in Figs. 60 and 61?

19. Why should the lands of a hand tap be wider than those of a machine tap?

20. Why is it necessary to use a releasing tap holder when tapping holes where the threads go to, or nearly to the bottom of the hole?

21. What is the effect of uneven heating of tool steel for hardening? Why?

22. Why is it advisable to use a form of grinder having two dead centers when a piece of work is required exactly round?

23. Why should the center of a mandrel be lapped to an angle of 60 degrees before the mandrel is ground to size?

24. What would be the result were the threads of a taper tap cut with a tail block set over to give the required taper?

25. Suppose a screw die hob were made with the same num-

ber of flutes and of the same proportions as hand taps. What would be the results if it were run into a screw-thread die which had been provided with clearance holes?

26. When are flat drills used? Why?

27. When making the adjustable reamer shown in Fig. 47 what would be the result when it was hardened if the slots were cut to the end of reamer?

28. When making the sleeve for the expanding mandrel shown in Fig. 65, why should it not be held in a grinder chuck when grinding the hole to size?

29. Why should steel for a cutting tool be chosen somewhat larger than finished size?

30. Why is it necessary to reheat large pieces after they have been hardened?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART II

---

1. Why is it not advisable to make the lands of screw threading dies wider than described? What is the result if they are made narrower?

2. Under what circumstances would you consider it advisable to use a counterbore, rather than a drill when enlarging a hole. Why?

3. Why would it not be considered good practice to turn the piece of stock represented in Fig 131 to size before drilling the holes and working the slots to size?

4. Why is it not advisable to make a hollow mill to be used in roughing out work, having more than 4 teeth?

5. Why is it advisable to give a finish hollow mill more than 4 teeth?

6. When hardening a hollow mill of the form shown in Fig. 147, why is it advisable to dip it in the bath with the cutting edges uppermost?

7. In using a forming tool why is it necessary to have the face of the tool at the height of the center?

8. Give the advantages derived from using a forming tool and holder of the design shown in Fig. 162.

9. Why is a milling-machine cutter more likely to crack when hardening than other forms of tools?

10. Why is it not good practice to ream holes in milling-machine cutters to finish size?

11. What is the result if the hole in a milling-machine cutter does not fit the arbor?

12. When is it advisable to use milling-machine cutters having interlocking teeth ?

13. When is it advisable to use milling-machine cutters having their teeth cut spirally ? Why ?

14. When is it advisable to cut the teeth of milling-machine cutters with a right-hand spiral ? When a left-hand spiral ? Why ?

15. State advantage gained in making milling-machine cutters with nicked teeth.

16. Why is it generally considered advisable to make milling-machine cutters that are larger than 6 or 8 inches diameter with inserted teeth.

17. When a blank for a milling-machine cutter that is to have inserted teeth is milled with slots that are at angle to the cutter axis, why is it not advisable to leave the faces of the teeth at that angle ?

18. If an emery wheel, 3 inches in diameter, is used in grinding the teeth of a milling-machine cutter, how many revolutions must it make in a minute in order to run at a peripheral speed of 5,000 feet per minute ?

19. Why is it not generally considered good practice to make key ways in milling-machine cutters with sharp corners ?

20. State in your own language the generally accepted meaning of the term "formed cutter" or form cutter.

21. Name some of the advantages derived from the use of formed cutters.

22. What would be the result if the faces of the teeth of a formed mill were not recut after they were backed off ?

23. When backing off the teeth of a formed mill, what would be the result of setting the forming tool above or below the center of the work ?

24. When making milling-machine cutters with threaded holes, why is it necessary to first thread the blank, then machine it on a threaded mandrel ?

What would be the result were the cutter machined to shape before threading the hole ?

25. When machining a piece of work having a threaded hole, why is it not advisable to screw the piece onto a threaded mandrel in such a manner that the shoulder of work is against the shoulder of mandrel when squaring the first end ?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART III

---

1. Why should undue accuracy never be indulged in when making drill jigs and similar tools?

Give examples where *extreme* accuracy is not desirable.

Give examples where it should be observed.

2. When making bushing holes in drill jigs by the method illustrated in Fig. 228 *why* are more satisfactory results obtained if the cutting end of counter bore is made of the form shown in Fig. 229.

3. State in your own words the reason for obtaining location of bushing holes in drill jigs by means of locating buttons and lathe indicator.

4. Why are drill jigs for permanent equipment provided with hardened steel bushings?

5. Name the different forms of drill bushings commonly used in jigs.

Name the good features of each.

Name the objectional features of each.

6. What is the objection to using the ordinary shop mandrel for holding bushings when grinding to finish size?

7. When drilling the block illustrated in Fig. 251 why is it advisable to first use the transfer drill shown in Fig. 254?

8. When reaming the holes in block shown in Fig. 251 why is it advisable to use the piloted single lip reamer? (Fig. 253)

9. Explain the office of the [illegible] punching press blanking die.

10. Why are blanking dies [illegible]

Where are they given [illegible]

Where are they given [illegible]

11. When making the die [illegible] punching press [illegible] available [illegible] would you get the desired result [illegible]

12. Why are the [illegible] made shearing?

When is it allowable [illegible]

13. When [illegible] work which is it necessary [illegible]

14. W[illegible] sectional dies?

15. W[illegible] die?

When are they [illegible]

16. W[illegible] irregular [illegible] Fig. 277 [illegible] face of the [illegible] of the aperture [illegible]

17. Exp[illegible]

18. W[illegible] rather [illegible]

19. W[illegible] explain the [illegible]

W[illegible]

20. W[illegible] result where the [illegible]

21. What [illegible] Fig. 289 name the [illegible] ation.

22. W[illegible]

23. Under what circumstances is it advisable to finish contact surfaces of gauges by lapping?

Why is it necessary?

24. Why should the ends of plug gauges be left as shown in Fig. 296 or Fig. 297 until the gauge is lapped to size?

25. When *finish* lapping a ring gauge to size why is it necessary to grind the lap perfectly round?

26. When are snap gauges used?

Why are they used in preference to a micrometer on ordinary work?

27. When making a snap gauge of the description shown in Fig. 306 why is it necessary to leave a small amount of stock on each contact surface until after the gauge is hardened?

28. When grinding the contact surfaces of snap gauges what points must be observed?

29. Give an example other than the one illustrated, where the use of a limit gauge would be advisable.

30. When making receiving gauges what points must be observed? Why?

31. When making the locating gauge shown in Fig. 327, why is it allowable to locate the first pin by *approximate* measurements and not the other?